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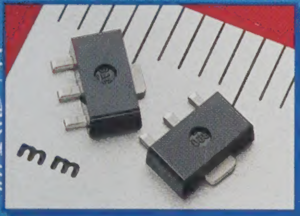
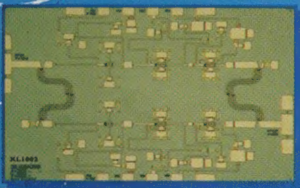
FEBRUARY 2005

HIGH FREQUENCY ELECTRONICS





New Product Focus: Connectors and Power Devices

INSIDE THIS ISSUE:

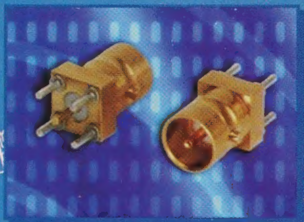
SiGe Microwave Circuits for Phased Arrays

Microwave Diode Package Performance

ESB Output Circuit Improves Class F Amplifiers

Tutorial: Using Advanced EDA Models

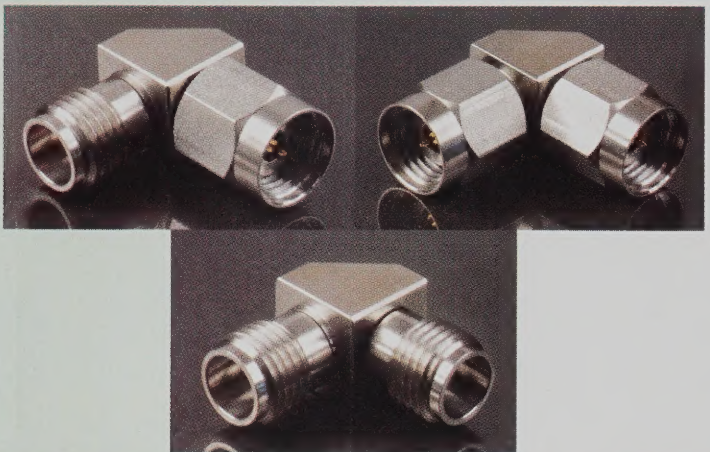
Technology Report—802.15, 802.16 and ZigBee



Ideas for today's engineers: Analog · Digital · RF · Microwave · mm-wave · Lightwave

Who has the Right Angle on RF, Microwave & Millimeterwave adapters?

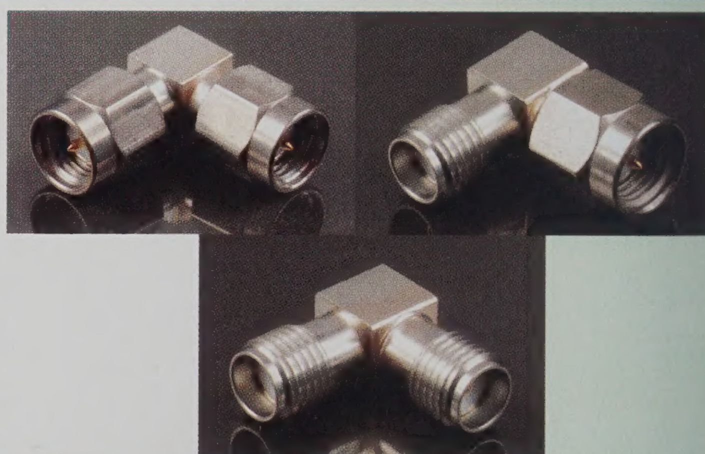
2.4mm, DC to 50 GHz



2.9mm, DC to 40 GHz

3.5mm, DC to 33 GHz

SMA, DC to 26.5 GHz



C.W. Swift & Associates, Inc., introduces S.G. McGeary Company's high-frequency coaxial adapters. Right-Angle In-Series configurations are available in 2.4mm, 2.9mm, 3.5mm and SMA interfaces. Straight In-Series and Between Series configurations are available in 1.85mm, 2.4mm, 2.9mm, 3.5mm, 7mm, SMA, SSMA, N & TNC Interfaces.

C.W. SWIFT & Associates, Inc.

RF, Microwave and mm-Wave Stocking Distributors

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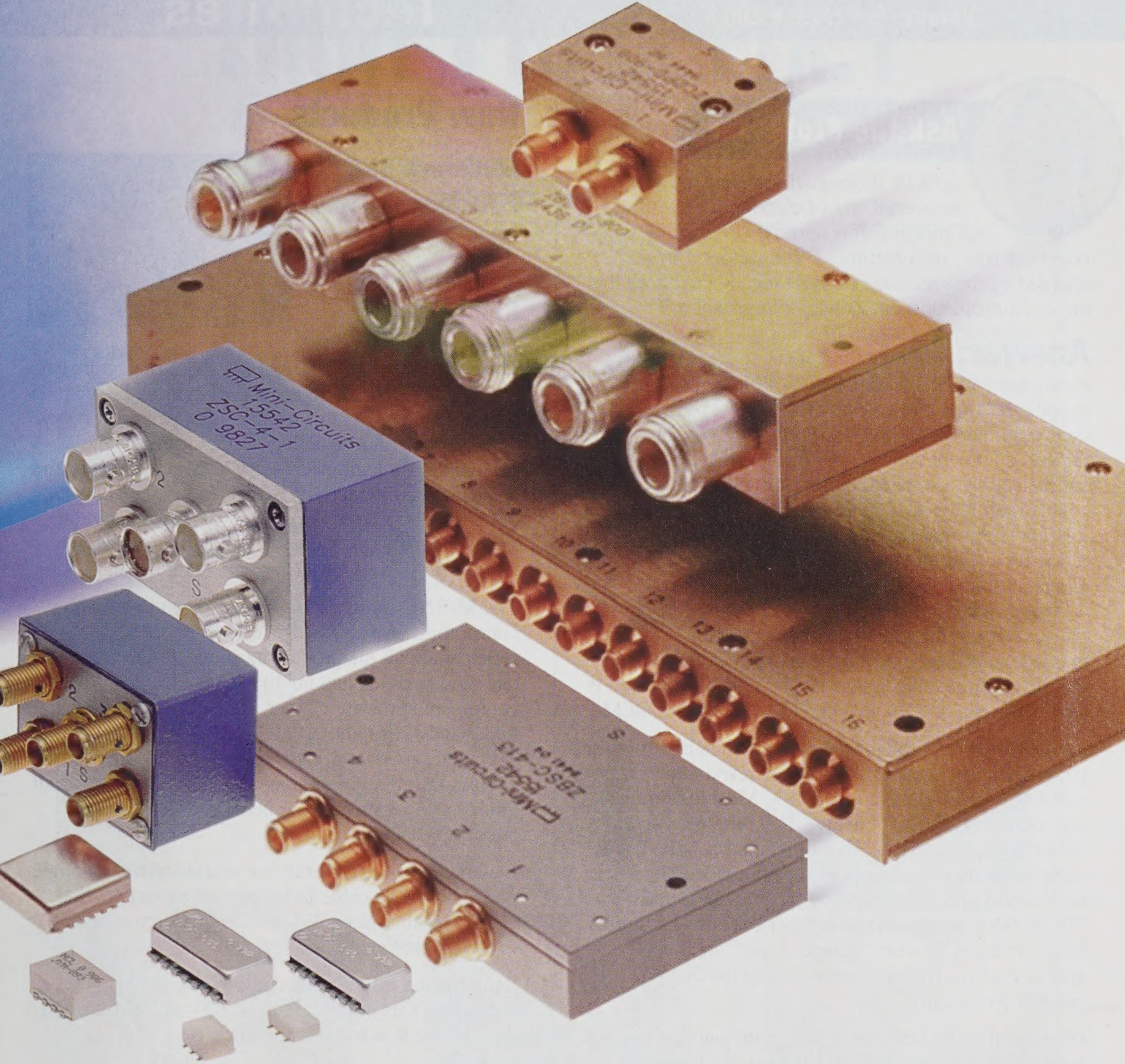
HFeLink 101

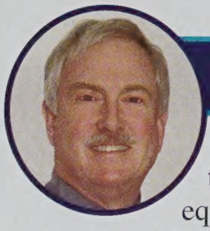


Mini-Circuits
15542
ZSC-4-1
0 9827

BLUE CELL DESIGNER'S HANDBOOK
RF/IF Designer's Guide

HIGH FREQUENCY Tech Bites

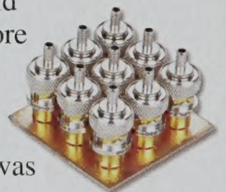
Volume 5 • FALL • 2004



Ask the Professor

As a PCB designer assigned to reduce the overall size of electronic networking equipment that is currently defined by high counts of BNC or sometimes F connectors, I'm stymied by the sheer size of these legacy interfaces that are so entrenched in the industry. Suggestions?

Answer: You're not the first confounded by this dilemma. One BNC supplier listened a few years back to their customer's struggle with Central Office equipment congestion issues, and suggested that a smaller connector could enable more devices - consequently more interconnects - per rack. In addition to requiring a substantial size reduction and retention of all other product attributes, a pivotal factor for the user was preservation of the cable installation process to allow continued use of their investment in fielded tooling and trained technicians. This M-BNC design is now being deployed in the telco/CO via network OEMs.

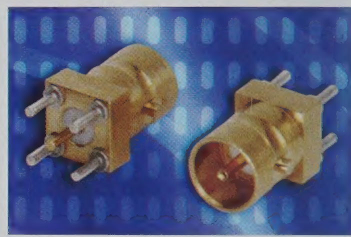


As previously reported, the BNC market is highly polarized in two segments with a corresponding variation in performance and price. Most are produced and marketed for cost-sensitive, low reliability, low frequency applications, and do not approach the telco standard in frequency response, mating cycle life, mechanical pull strength or service life characteristics. The M-BNC products now surfacing are subject to this same variation between "Carrier Class" and "hobby grade" quality. Be sure to match your need to the product you specify.

For example, the DS3 line is where the public switched network optical data streams are converted into electricity for routing and other signal management work. BNC connectors are used here to support highly shielded coaxial line rates and signal egress. These "Carrier Class" connectors are designed and built to a standard quite separate from those used for other applications. Another network that now needs "Carrier Class" long life reliability and high performance is CATV which is rushing to deploy high definition television (HDTV), an application that requires new attention to signal integrity issues.

New Products

Miniature BNC PCB-Mount Jack: 40% Smaller and 99.999% Reliability



The Trompeter 250 Series of M-BNC connectors has recently expanded with the addition of the UCBJ250S. A unique feature of this new 75-ohm pcb-mount jack is the robust, reinforced leg set that provides the mechanical strength necesssary to compensate for the torque related to the jack's small footprint. This jack has undergone extensive reliability testing including mixed flowing gas, thermal cycling, thermal aging, and NEBS testing for telco grade compliance.

The M-BNC series enables a significant increase in connector density. The Trompeter products in this series retain all the product attributes of the classic telco grade BNC, making the series ideal for OEM equipment applications that involve high data rates, high bandwidths and/or high frequencies. The Trompeter product design, performance, material choices, installation tooling compatibility, and overall quality are consistent with network "Carrier Class" telco DS3 data rate applications.

Included in the 250 Series are straight and right angle plugs, bulkhead cable jacks, as well as straight and 90° pcb-mount jacks. Pcb-mount jacks are available in both nickel and gold plate.

Samples and information can be obtained by contacting Customer Service at 800-982-2629, or on the website at **www.trompeter.com**.

About Trompeter

Trompeter produces interconnect products, including RF connectors, patch panels, cable assemblies and related tools for the telecommunications, broadcast, military/aerospace and instrumentation markets worldwide. Let us help you with your next design challenge that includes coaxial signal integrity.

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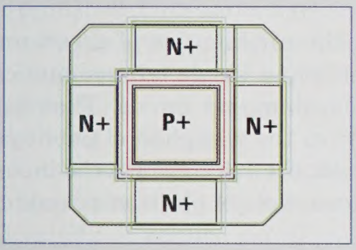
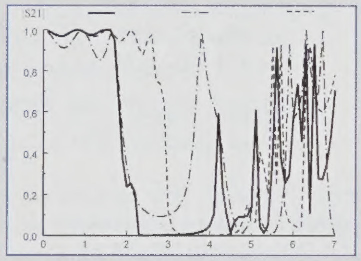
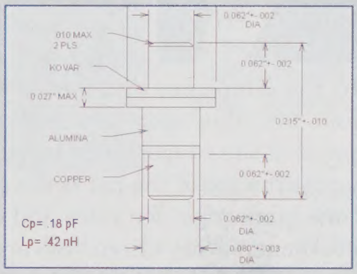
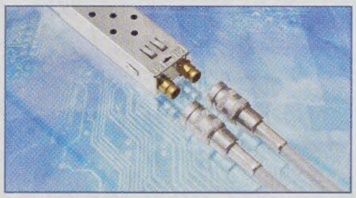
Inside This Issue









Regular Columns

On the Cover—The products shown in the photos on our cover (and above) can be seen in the special New Products sections featuring Connectors and Power Devices.

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Convergence: It's Not Just a Buzzword Anymore

Gary Breed
Editorial Director

Convergence—the combination of previously discrete services into a single telecommunications system—is sneaking up on us. That is, it is sneaking up on us from the viewpoint of public perception, but it is an avalanche rolling down the mountainside in the boardrooms of major electronics and telecom companies.

It's not happening all at once, like a few futurists suggested, and it's not happening as fast as was hoped by the companies that buried thousands of miles of fiber back in the 1980s and '90s. But, there are several recent developments that are significant parts of the convergence movement.

At the top of the list is the growth of wireless technology. Convergence's "one giant pipe" for voice and data could never happen if it couldn't reach everyone, everywhere. Several US cities were in the news recently, announcing plans to develop metropolitan area wireless networks (MANs) using various combinations of wireless point-to-multipoint, fiber optics and wireless LAN hot spots. In addition, the next generation (whether 2.5G or 3G) of the wireless "phone" system is beginning to spread, which will provide relatively high-speed data capability to every handset user.

The second item on my list is Internet use by ever-greater numbers of people. According to a recent news report, Internet usage has reached the point where adults are now better than kids at navigating the Internet to find the information they need! Cable modems, DSL and enhanced dial-up services have increased the speed of everyday access, supporting both greater usage and additional services.

Here's a concept that seemed to make sense the first time I heard it—convergence will follow a period of the opposite trend, a proliferation of discrete services. The simple voice telephone is the best example. From your home, you can make a phone call by traditional copper landline, via a CATV system, by cell phone, using Voice-over-Internet Protocol (VoIP) or even with a satellite phone. Such a range of services is incredibly inefficient! If all of them are in place, each service needs a unique phone number and an array of hardware to make them function.

Video and audio entertainment is following the same pattern. You can get programming via terrestrial broadcast, CATV distribution, DBS satellite, MDS microwave broadcast, recorded media or Internet download.

The logical question is, "Do we need all of these choices?" Well, right now, yes we do. But it is easy to imagine how many of them could be combined into a single system, greatly enhancing the convenience to consumers.

Convergence Challenges

I see two major challenges for convergence to continue—security and competition.

Security of the actual transmission of data appears to be manageable, with advanced encryption well-established. Unless the hacker community uncovers the Rosetta Stone of encryption (yes, I enjoyed the movie *Sneakers*), this part of security is not a problem.

The other part of security is the use of accumulated data. Our current diversity of service providers means that personal data is compartmentalized—there is no single place where it is collected. If we have a single point of access for our communications, it will be easier for identity theft, or at least identity intrusion, to occur.

In the US, the biggest barriers to total convergence are our antitrust laws. Who runs the "single point access" that provides phone, Internet, entertainment, banking, etc.? It's essentially the same issue as AT&T and the telephone, or Microsoft and PC operating systems. I'll be watching with interest!

When Not to Converge

I don't expect convergence to be the entire answer to our communication needs and preferences. The giant retail stores have not put all the small shops out of business, either. At the very least, there will be "boutique" services that are highly individualized, and people like me will do things the old way just for our personal enjoyment.

World politics and economics will prevent global convergence, so existing technologies will continue to be used where they still make sense. Developing nations may leapfrog some steps as they implement improved services, but it will be a long time before they reach the level of the economic giants, which will have moved ahead in their own ways, of course.

As you might guess, my overall opinion on the value of convergence is, "It depends." There are many areas where integrated, convenient communications makes perfect sense. But, being individuals, we all will have preferences in the way we live that no single provider will ever be able to satisfy.

Conferences

February 16-17 and March 2, 2005
2005 HFSS Users Workshops
February 16-17: San Jose, CA
March 2: Boston, MA
Information: Ansoft Corp.
http://www.ansoft.com/hfworkshop05

February 16-17
EMC Zurich 2005—Topical Meetings on Biomedical Electromagnetic Compatibility
Zurich, Switzerland
Information: Asst. Prof. Elise Fear, Univ. of Calgary
Tel: 403-210-5413; Fax: 403-282-6855
E-mail: fear@enel.ucalgary.ca
http://www.emc-zurich.ch

February 23-24, 2005
IDGA's Software Radio Summit
Arlington, VA
Information: IDGA web site
http://www.idga.org

March 1-3, 2005
ISART 2005—International Symposium on Advanced Radio Technologies
Boulder, CO
Information: ISART web site
E-mail: wallen@its.bldrdoc.gov
http://www.its.bldrdoc.gov/meetings/art/index.php

March 8, 2005
UCLA's WINMEC Annual Conference
Los Angeles, CA
Information: WINMEC web site
http://winmec.ucla.edu

March 14-16, 2005
CTIA Wireless 2005
New Orleans, LA
Information: CTIA web site
http://www.ctia.org

March 22-24, 2005
RF & Hyper Europe 2005
Paris, France
Information: BIRP (show organizers)
Tel: +33 1 44 78 99 30; Fax: +33 1 44 78 99 49
E-mail: hyper@birp.fr
http://www.birp.com/hyper

April 5-7, 2005
GeMiC 2005—German Microwave Conference
University of Ulm, Germany
Information: University of Ulm
E-mail: gemic@gemic.e-technik.uni-ulm.de
http://www.GeMiC2005.de

April 7-8, 2005
WAMICON 2005—IEEE Wireless and Microwave Technology Conference
Clearwater, FL
Information: Conference web site
http://www.wamicon.org

April 16-21, 2005
NAB2005
Las Vegas, NV
Information: National Association of Broadcasters
E-mail: register@nab.org
http://www.nab.org

April 18-19, 2005
IEEE Sarnoff Symposium
Princeton, NJ
Information: Gerhard A. Franz
E-mail: sarnoff2005@agfranz.com
http://www.sarnoffsymposium.org

May 22-25, 2005
EIT 2005—IEEE International Conference on Electro Information Technology
Lincoln, NE
Information: Conference web site
http://www.nuengr.unl.edu/eit2005

May 30-June 1, 2005
VTC 2005 Spring—Vehicular Technology Conference
Stockholm, Sweden
Information: Conference web site
http://www.VTC2005Spring.org

June 12-17, 2005
IMS 2005—IEEE MTT-S International Microwave Symposium, RFIC 2005—IEEE Radio Frequency Integrated Circuits Symposium, and 65th ARFTG Conference
Long Beach, CA
Information: *Microwave Journal*
E-mail: mwj@mwjournal.com
IMS 2005: http://www.ims2005.org
RFIC 2005: http://www.rfic2005.org
ARFTG: http://www.arftg.org

July 3-8, 2005
IEEE AP-S International Symposium and USNC/URSI Meeting
Washington, DC
Information: Conference web site
http://apsursi2005.org

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http://uclaextension.edu/shortcourses

Charge-Coupled Devices/CMOS Imaging Sensors and Application
February 28-March 4, 2005, Los Angeles, CA
Satellite Communications Networks and Applications: Creating Next-Generation Systems and Services
March 21-25, 2005, Los Angeles, CA

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http://www.aticourses.com

Antenna & Array Fundamentals
February 28-March 2, 2005, Colorado Springs, CO
Microwave & RF Circuit & Component Modeling
March 8-11, 2005, Beltsville, MD
Electronic Warfare Overview
March 23-25, 2005, Beltsville, MD
Synthetic Aperture Radar—Fundamentals
April 4-5, 2005, Chantilly, VA
Synthetic Aperture Radar—Advanced
April 6-7, 2005, Chantilly, VA

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E-mail: info@besserassociates.com
http://www.besserassociates.com

March 7-11, 2005, San Diego, CA
Applied RF Techniques I
Applied RF Techniques II
RF and Wireless Made Simple
Frequency Synthesis and Phase-Locked Loop Design
Adaptive Receivers & Software Radio for Wireless Communications
Adaptive Antenna Arrays: Fundamentals for Wireless Communications
Digital and Analog Linearisation Techniques For RF Power Amplifier Systems
RF CMOS Design
Signal Integrity for Digital Designers
March 14-18, 2005, Sunnyvale, CA
RF Measurements: Principles & Demonstration
Design and Simulation of Wireless Radio Systems
Implementing Wireless Digital Modulation Products
April 25-29, 2005, Phoenix, AZ
Applied RF Techniques I
RF Transceiver Architecture, Design and Evaluation
Short Range Wireless Networks
Wireless Circuits, Systems and Test Fundamentals
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Offered monthly—Next course is February 16-17, 2005

Calls for Papers

Wireless 2005—17th Annual International Conference on Wireless Communications
Calgary, Alberta, Canada
Conference Dates: July 11-13, 2005
Submission Deadline: February 28, 2005

Topics:
Papers are solicited in all areas of wireless research as well as market studies, trials, exploratory developments and standards. Topics include (but are not limited to): MIMO (Multi-input/Multi-output); Ad Hoc Systems; Ultra-Wideband; Home Networking; Nonlinear Receivers; Wireless Applications/Standards; CDMA; Multi Carrier Systems; Channel Estimation/Equalization; Modulation, Coding & Detection; Antennas/Smart Antennas; Circuits and Subsystems; and Resource Allocation/QoS.

Information: Conference Secretary
Ms. Leile Southwood, TRLabs
#280, 3553-31 St. NW
Calgary, AB, Canada T2L 2K7
Tel: 403-289-3140
Fax: 403-282-5870
E-mail: wireless@trlabs.ca
http://www.trlabs.ca/wireless

High Frequency Electronics *has an ongoing need for articles on topics of interest to engineers working in this specialty, at all technical levels from tutorial to advanced. Send abstracts or other brief description of proposed articles to the Editorial Director: gary@highfrequencyelectronics.com*

Technology News

WJ Communications, Inc. announced it has begun volume production shipments of its new high efficiency power amp, the ECM168. The ECM168 is the first in a line-up of a series of power amplifiers primarily targeted towards the PAS/PHS wireless infrastructure markets.

AR Modular RF has announced that its battletested KMW1030 (20 watts minimum CW, 30-512 MHz) man-pack booster amplifier has been successfully integrated into a mobile briefcase configuration by **Diversified Technology, LLC**. The new configuration includes associated encrypted radio and battery/power supply systems and will be deployed in high-level government security units.

Business News

Cobham plc's Chelton Microwave Corp. agreed to purchase a **Remec, Inc.** defense and space unit for about $260 million in cash. The unit employs 1,000 workers in San Diego who are expected to remain with the company after the purchase. The transaction is expected to close in the first quarter of 2005 and needs to be approved by regulators and Remec shareholders. Remec intends to distribute a large part of the proceeds of the sale to its shareholders after the sale is completed.

Advanced Power Technology, Inc. announced that it has entered into a definitive agreement to acquire **PowerSicel, Inc.** The purchase provides APT with a center for technological and innovation excellence for compound semiconductors, starting with silicon carbide, as well as significant development capability for commercial devices utilizing currently available compound semiconductor technologies. In addition this purchase strengthens APT's intellectual property portfolio in the silicon carbide area. The products to be developed will address target applications in RF power such as avionics, radar, broadcast, satellite communication and wireless communications as well as applications in power switching such as power conversion and motor drives. Under the terms of the agreement, APT will issue approximately $5.4 million in cash in exchange for all of the existing shares of PowerSicel, 60,961 APT stock options in exchange for the PowerSicel stock options and 19,400 APT stock options for the retention of key employees.

XMA Corporation and **BFi OPTiLAS** announce the signing of a distribution agreement. Under terms of the agreement, BFi OPTiLAS will distribute XMA's full line of standard RF & microwave components including terminations, attenuators and other passive products in the European markets.

Richardson Electronics announced it has signed a distribution agreement with **Fractus**. Under the terms of the agreement, Richardson will operate as a global distributor for Fractus's complete line of embedded antennas for short-range wireless applications, filling a need in Richardson's components solutions line card. Richardson's product offering will now encompass a wide array of components for the emerging Broadband Wireless Access market to accommodate WiFi, WiMAX, Zigbee and Bluetooth® technologies.

Eagleware Corporation announced that the company name has changed to **Eagleware-Elanix Corporation** to reflect Eagleware's recent acquisition of **Elanix, Inc.** In addition, the company announced a new version of SystemView, SystemView by Elanix® 2005, with library support for the emerging Ultra-Wideband (UWB) IEEE standards.

WJ Communications, Inc. has announced that all products in the SOT-89 package are now available in the environmentally-friendly lead-free/green/RoHS-compliant packages. The lead-free and green part number will end in "G" to signify compliance with industry standards. The company now offers over 80 percent of its available devices in lead-free and green packaging. All WJ lead-free products are also RoHS compliant; green products are lead-free, RoHS compliant, and have limitations on other specific chemicals as well as being backward compatible with lead-based SMT processing. All of WJ's lead-free products will meet the requirements of the European Union to minimize hazardous substances throughout the electronics industry.

Mimix Broadband, Inc. and **Macquarie University** have recently been awarded more than US $500k in research funding under the **Australian Research Council's (ARC) Linkage-Projects Scheme**. Through 2007, ARC will fund AUS $640k to the project, which will include two Australian Postgraduate Award (PhD) researchers and a Post Doctoral researcher. The research will be jointly led by Associate Professor Tony Parker, Head of Macquarie's Department of Electronics, and Dr. Simon Mahon, Director of MMIC Design at Mimix Broadband, Inc.

State of the Art, Inc. (SOTA) has been granted qualification by the Defense Department (DSCC of Columbus, OH) for the new MIL-PRF-32159 ZERO OHM chip resistor. The new specification provides zero ohm jumpers at three product levels: Space level T (including 100 percent burn-in), product level M and product level C. Military grade jumpers are available in 13 case sizes with solderable, wire bondable and epoxy bondable termination finishes, and are identical to our Mil-PRF-55342 product.

Palomar Technologies has announced an agreement to supply Fabrinet with optoelectronic and complex packaging assembly equipment to expand Fabrinet's capabilities in volume assembly of terminal-active optoelectronic components and precision microelectronic packaging. Fabrinet will add a Palomar LDA Laser Diode Attach Component Assembly Cell and a Model 8000 high speed thermosonic ball and stitch wire bonder to its new manufacturing facilities in Bangkok, Thailand. The LDA will increase the quality, throughput and yield of optoelectronic components manufactured by Fabrinet. Fabrinet

will use the 8000 for wire bonding microelectronic packages, including most semiconductor-based interconnect applications such as hybrids and gold ball bumping.

Applied Wave Research, Inc. (AWR®) has announced that it is teaming with **Rohde & Schwarz**. The partnership will offer test solutions using Rohde & Schwarz high-specification T&M instruments with AWR software. These solutions provide bi-directional transfer of data between instruments and EDA software, as well as the ability to use measured data in place of models when simulating complex systems. In addition, Rohde & Schwarz will strengthen the AWR sales channel by providing Microwave Office® and Visual System Simulator™ (VSS) design solutions throughout Europe.

AeroComm, Inc. announced its move into a larger and more versatile world headquarters. The 30,000-square-foot office, R&D lab and manufacturing facility, located in the southwestern suburbs of Kansas City, will allow AeroComm to triple in-house engineering and manufacturing capabilities. The company anticipates further exponential sales growth in 2005, due in part to new RF product developments like waterproof enclosures, ethernet interfaces, masterless protocol, Zigbee standard modules and higher-power European band products.

Sales Appointments

Applied Wave Research, Inc. has announced the appointment of **TeraSoft, Inc.** as a value-added reseller of AWR software in Taiwan. Under the terms of the agreement, TeraSoft will provide electronic systems and integrated circuit (IC) designers with AWR products and technical support. TeraSoft will handle the sales, support and administration for the complete line of AWR next-generation products, including Microwave Office® design suite for radio-frequency (RF) and microwave design, Visual System Simulator™ design suite for system design and Analog Office™ design suite for analog and RFIC designs.

Julie Williams returns to **Dow-Key** as Territory Sales Manager responsible for Southern California and Canada. Ms. Williams brings with her a wealth of market knowledge, customer relations skills and switch expertise. Her main responsibility will be the development of new customers and opportunities.

People in the News

UltraSource, Inc. has announced the hiring of **Michael J. LoFrumento** as Director of Sales. Prior to joining UltraSource, Mr. LoFrumento was employed by Natel Engineering Co, Inc. of Chatsworth, CA. Prior to joining Natel, Mr. LoFrumento was instrumental in creating an extensive sales and marketing strategy for a microelectronics ceramic packaging company. In his role as Director of Sales, Mr. LoFrumento will be responsible for managing UltraSource's worldwide sales network and supervising new business development.

XMA Corporation announces the appointment of **Daryll Saunders** as VP, Engineering & Operations. In this position, Daryll will be responsible for expanding XMA's engineering and manufacturing capabilities in both Manchester, NH and Tianjin, China. Daryll brings over 20 years of technical and manufacturing management experience to his new position with XMA. Most recently Daryll served as General Manager of the Aeroflex China facility in Nanjing for two years, Engineering Manager at Aeroflex/Inmet for four years, and as Outsourcing Manager and Member of Technical Staff at Tyco M/A-COM for various products manufactured in Puerto Rico, Dominican Republic and China for 13 years.

Park Electrochemical Corp. announced the appointment of **Howard R. Elliott** as the President of **Neltec, Inc.** Mr. Elliott has over 20 years of management experience in the high-performance printed circuitry materials industry. He has held senior engineering, technology, research and operations positions at Isola USA Corp., Matsushita Electronic Materials, Inc., Polyclad Technologies, Inc., Allied-Signal, Inc., Hughes Aircraft Company and Texas Instruments, Inc. Park Electrochemical Corp. also announced the appointment of **Jonathan Spiegel** as Product Director. He will be responsible for management of a portion of the company's advanced technology products. Mr. Spiegel will coordinate product development activities from research and development project criteria identification through product commercialization. Mr. Spiegel joins Park with many years experience in product development and management.

Renzo Tani, a former CEO of **Siemens SpA** in Italy, began his three-year term as **IEC** president on 1 January 2005 with the aim of developing closer ties to industry, organizations and governments. Tani says the IEC is an organization with a big task and a large commitment working in a difficult environment. Because there is a growing number of countries participating in electrotechnology and telecommunications around the world, harmonizing all points of view is increasingly difficult.

David Wightman, President, **Dow-Key Microwave**, will now serve a dual role as President of Dow-Key and **K&L Microwave**. To assist him in his new responsibilities, Wightman appointed **Adolf Cheung** to General Manager, Dow-Key Microwave. His main objective will be to carry on Dow-Key's focus on continuous improvement and superior customer service throughout the entire organization.

Broadband SiGe Monolithic Microwave Control Circuits

By R. Tayrani
Raytheon Space & Airborne Systems

A current SiGe process was used to fabricate phase shifter and switch circuits for phased array radar applications, requiring special attention to the characteristics of the PIN diodes

This paper reports the performance of several broadband SiGe monolithic microwave control circuits suitable for phased array radar applications. The amplitude and phase control MMICs are based on an optimized SiGe PIN diode fabricated using the IBM 5-HP SiGe foundry process. Utilizing this diode, several control circuits were designed, including a broadband (1-20 GHz) monolithic SPDT switch, a five port transfer switch, and a 6-bit phase shifter, all operating over 7-11 GHz.

Device Design

The IBM silicon-germanium technology permits the integration of advanced MMICs, low power VLSI digital electronics and low frequency analog circuits in a single high yield process. The availability of several high performance microwave passive and active devices on the same wafer, including SiGe HBTs, PINs and varactors, etc., makes the IBM SiGe technology an exciting paradigm for innovative circuits for RF and microwave communication systems.

Fundamental to the success of any microwave control function is a high performance PIN device. The performance of the PIN is dependent on its material doping profile as well as its layout. In the IBM 5HP SiGe process, the doping profile of the PIN diode is closely linked to that of the HBT through sharing of three HBT material layers, namely, the buried N+ sub-collector layer, the N-collector layer and finally the P+ SiGe base layer.

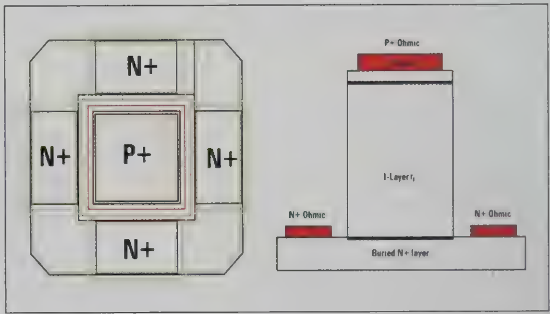


Figure 1 · SiGe vertical PIN diode (dimensions 7 x 7 µm).

These layers have been used to form the cathode, the I-region, and the anode of the PIN diode, respectively. The material profile in IBM 5HP process is optimized for achieving a high F_t HBT performance which somewhat limits its collector thickness and, consequently, the PIN's I-region thickness to approximately one-half micron. Since the material profile of the PIN is rigid due to the HBT's performance requirements, the PIN layout design should be optimized to achieve optimum microwave performance. Figure 1 shows the layout of such a vertical optimized PIN design having a square anode contact that is surrounded by a continuous cathode contact. Such a device has a periphery-to-area ratio of only 0.56, an important design factor for minimizing the device forward bias microwave resistance (R_f).

The forward bias resistance of the PIN diode (R_f) is the sum of the current independent contact resistance (R_c) and current dependent resistance (r_f), caused by the conductivity modulation of the intrinsic region. The current dependent resistance is due to the injection of the holes and electrons into the

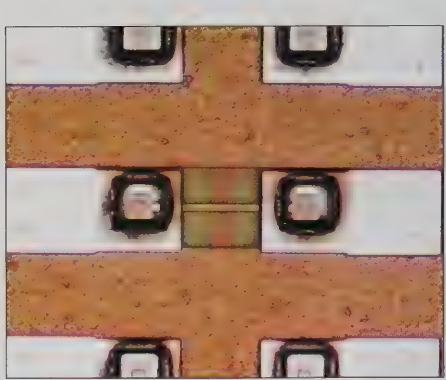


Figure 2(a) · Shunt SiGe PIN diode across 50 ohm CPW lines.

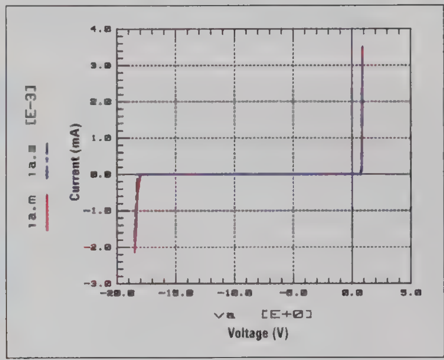


Figure 2(b) · Measured and modeled (using ICCAP) DC-IV characteristics of the shunt diode (80).

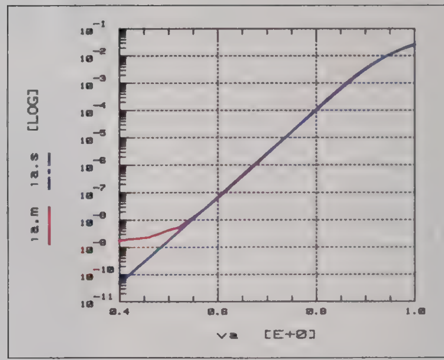


Figure 2(c) · Measured and modeled (using ICCAP): log I (A) vs. voltage (V).

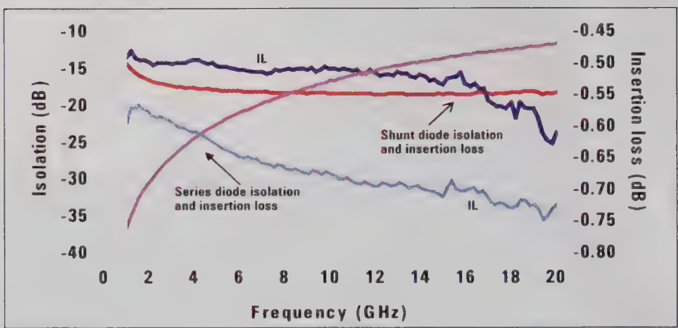


Figure 2(d) · Microwave performance of series and shunt diodes (I_f = 2 mA, V_f = 1.0V, V_r = –1 V).

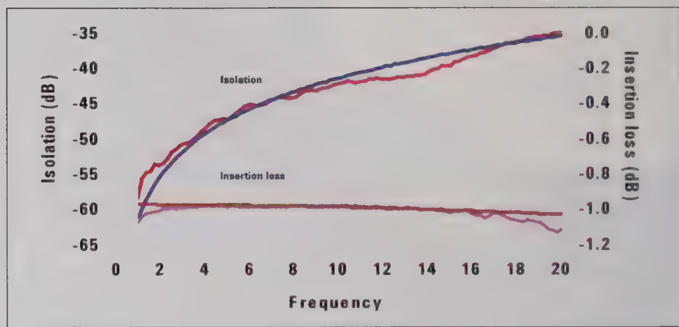


Figure 2(e) · Measured and modeled (using ADS) performance of an integrated series-shunt diode (I_f = 2 mA, V_f = 1.0 V, V_r = –1 V).

PIN Area μm^2	IL (dB) 10 GHz	Iso. (dB) 10 GHz	C_j (fF) –1 V	R_f (Ω) V_f = 1 V
80 Shunt	0.5	18.0	32	3.5 @ 2 mA
50 Series	0.7	18.0	20	9.0 @ 2 mA

Table 1 · Measured performance and extracted C_j and R_f values.

intrinsic region from the forward biased P^+ and N^+ contact regions. This resistance is given by:

$$r_f = \frac{l_i^2}{2\bar{\mu}\tau I_{DC}} \tag{1}$$

Where l_i is the thickness of the intrinsic region; $\bar{\mu}$ is the average electron and hole mobility; and (τ) is the minority carrier life time.

Device Performance

Figure 2(a) illustrates a fully fabricated 80 μm^2 shunt device in a 50 ohm system. As it can be seen, the buried PIN is accessed by six vias that connect the device terminals to the input-output launching pads. The transmission lines are formed on a 15-micron thick polyimide layer that is deposited on the surface of the SiGe substrate. Good agreement has been obtained between the modeled and the measured DC current-voltage characteristics of the diode as shown in Figures 2(b) and 2(c). The diode follows a parallel plane diode behavior, given by Eq. (2), over seven orders of magnitudes.

$$I = I_s\left(\exp\left(\frac{qV}{nKT}\right) - 1\right) \tag{2}$$

The measured and modeled data on saturation current (I_s), the ideality factor (n), and the junction revere breakdown voltage (V_b) are found to be: I_s = 1.2 x 10^{-17}, n = 1.1 at T = 300K, and V_b = 18 V. The value of (n) has a significant effect on the performance of the PIN diode [1-3].

Figure 2(d) illustrates the RF performances for typical 50 μm^2 and 80 μm^2 diodes when placed across or in series with 50 ohm CPW input-output transmission lines. As can be seen, good broadband performance has been obtained for both series and shunt devices at a low dissi-

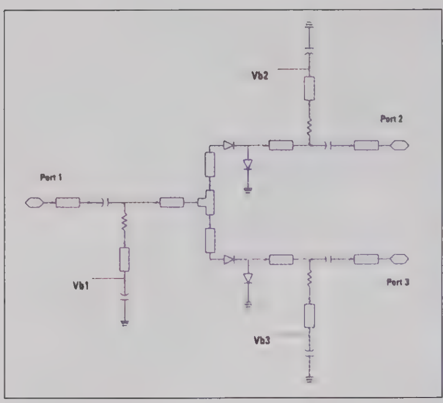


Figure 3(a) · SPDT switch chip schematic.

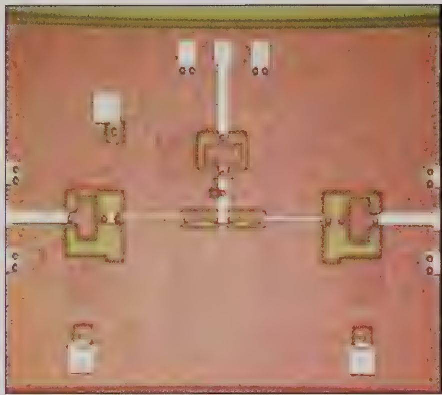


Figure 3(b) · SiGe SPDT switch chip (1.0 × 0.42 mm).

pation power of 2.0 mW. Table 1 summarizes the extracted values for junction capacitance and the total forward biased resistance (R_f) for both devices.

The measured and modeled performance for a typical integrated series-shunt diode pair (50 series, 80 shunt) is shown in Figure 2(e). To achieve a broadband RF operation for this structure, the distance between the two diodes was set to approximately 10, thereby minimizing its associated parasitics.

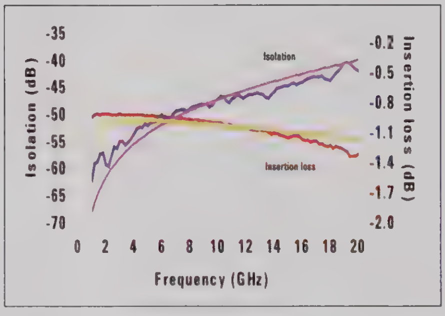


Figure 3(c) · Measured and modeled (using ADS) SPDT switch performance.

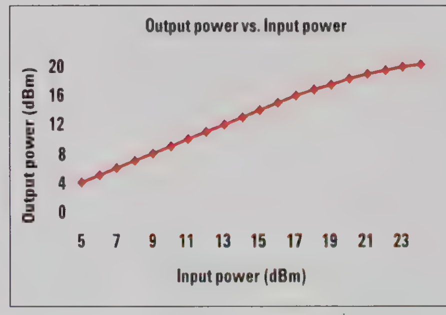


Figure 3(d) · Switch input power at 1-dB compression.

Broadband (1 to 20 GHz) SPDT Switch

The series-shunt integrated diode structure described above was used to design a broadband SPDT switch with on-chip resistive biased networks that operates over 1 to 20 GHz bandwidth. All aspects of the circuit design and device modeling were performed using Agilent ADS simulators [4]. Figure 3(a) shows the SPDT switch schematic having a series-shunt diode combination in each arm. This topology was chosen as the best compromise between minimizing the insertion loss and maximizing the switch isolation. On-chip resistive bias networks were also employed to ensure broadband switching performance and smaller chip size as illustrated in Figure 3(b).

The 1500 ohm bias resistors in this design use 340 ohms per square polysilicon thin film resistors and the MIM capacitors are based on 0.7 fF/μm^2 thin dielectric film (SiO_2) capacitors. Referring to Figure 3(a), a through-path between ports 1 and 2 exists when V_{b2} = –6.8V and V_{b1} = 0, causing the series diode to become forward biased at 2 mA while the shunt diode is reversed biased. Similarly, an isolation path exists between ports 1 and 3 when V_{b3} is set at (3.8 V, 2 mA). The total DC power consumption for this design is only around 22 mW for a typical switch. As shown in Figure 3(c), a through-path loss of 0.9 to 1.3 dB and an isolation path loss of 60 to 40 dB over a wide frequency range (1 to 20 GHz) have been measured. Also shown is the close agreement obtained between the switch measured and simulated data. A similar chip without the on-chip resistive bias networks was also measured, requiring only 4.0 mW of DC power for maintaining the same switch performance.

The input port power handling capability of the switch is shown in Figure 3(d) indicating the 1-dB insertion loss compression point occurs at around 19 dBm when mea-

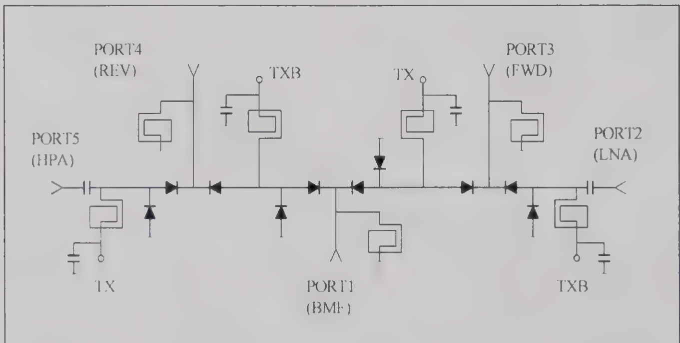


Figure 4(a) · Transfer switch schematic.

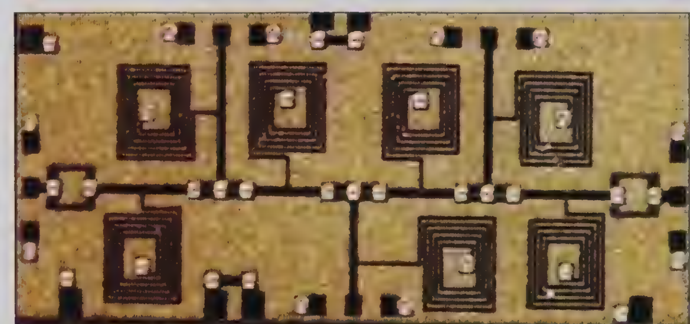
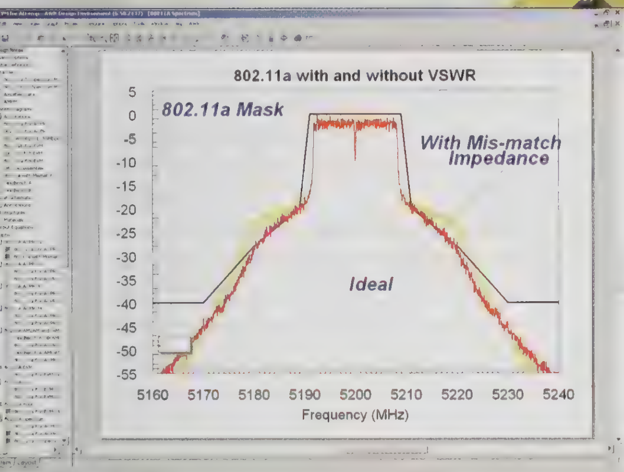


Figure 4(b) · Transfer switch chip (3.2 × 1.4 mm).

AWR



Getting a clear upfront view of VSWR effects can eliminate a lot of unexpected system turbulence downstream. Traditional software assumes ideally matched interconnections between models. But the real world involves impedance mismatches, phase noise, and RF nonlinearities that can capsize your project or turn your timetable upside down. Only Visual System Simulator™ has the patent-pending RF models to show the impact of VSWR on BER. And cascaded budget analysis can monitor the entire RF link and map out potential drop-offs before your system hits the rocks. Download a 30-day demo from mwoffice.com or call 310-726-3000 for details.

Visual System VSS Simulator 2004

Understand impedance mismatches before you take the plunge.

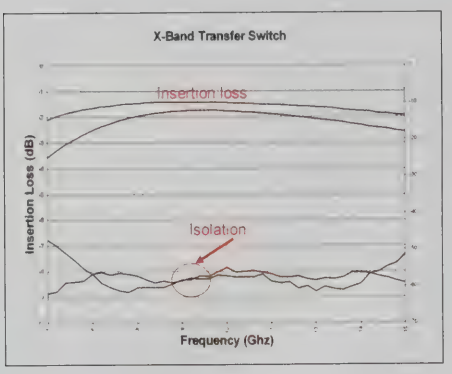


Figure 5(a) · Switch measured insertion loss and isolation.

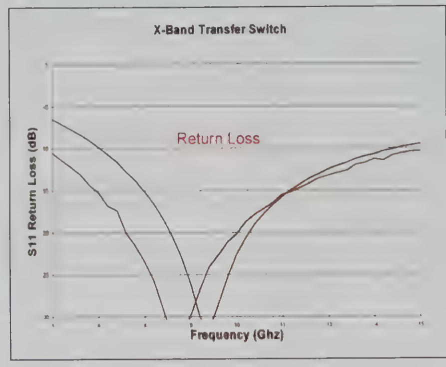


Figure 5(b) · Switch measured return loss.

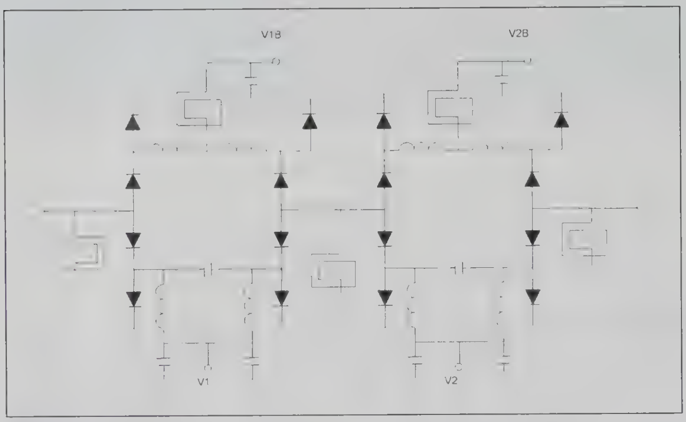


Figure 6 · 180/90 degrees and 45/22.5 degrees phase 2-bit schematic.

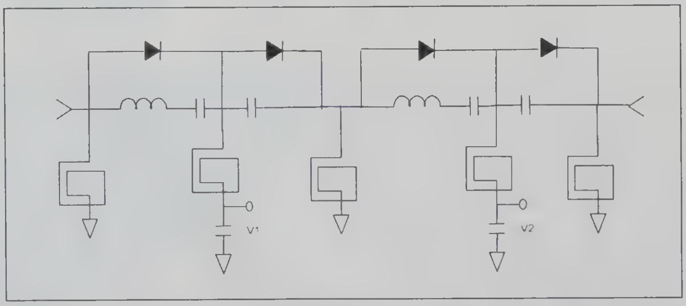


Figure 7 · 11.25/5.625 degrees phase bit schematic.

sured under the nominal bias condition described above. The switching speed and the third order intercept point were both evaluated at 10 GHz. The switching speed was found to be less than one nanosecond and the third order intercept point around 30 dBm at –3 dBm input RF power.

X-band SiGe MMICs

IBM's SiGe BiCMOS 5HP process offers the potential to integrate high levels of microwave circuitry with analog and digital circuits. Microwave functions traditionally performed by gallium arsenide MMICs can now be combined with the analog/digital functions of silicon based ASICs on a single chip. As an example of higher microwave integration levels, several X-band SiGe MMICs, including a transfer switch, a 6-bit phase shifter, a 5-bit attenuator and a variable gain cascode amplifier, is described in this section. The post SiGe topside process is described in details in the section "Topside Polyimide Technology."

Transfer Switch—Figure 4(a) shows the circuit schematic of a 5-port transfer switch containing 10 optimized SiGe PIN diodes. The circuit design is suitable for applications where Common Leg Circuit (CLC) architecture [5] is employed for the realization of phased array T/R modules. In the CLC topology, the transfer switch would enable the amplifier gain control and phase control circuitries to be shared by both transmit and receive signal paths. The switch design is based on a series-shunt 50 diode combination as the best compromise between minimizing the insertion loss and maximizing the switch isolation. The simplicity of the circuit design is the result of the low parasitic capacitance and resistance of the SiGe PIN diodes leading to a compact chip size shown in Figure 4(b). The switch measured insertion loss, isolation, and return loss are shown in Figures 5(a) and 5(b). The transfer switch demonstrates a path loss of 1.4 to 2.1 dB and an isolation of >55 dB across 7 to 11 GHz. The measured input and output return losses are better than 10 dB over the same frequency band (Figure 5(b)).

6-bit Phase shifter—The phase shifter design consists of six digital bits (180, 90, 45, 22.5, 11.25 and 5.625 degrees) cascaded in a linear arrangement. This provides 64 phase states between 0 and 360 degrees, in increments of 5.625 degrees. The 180, 90, 45 and 22.5 degree phase bits switch between Pi- and/or T-type high-pass/low-pass phase shift networks using two single pole double throw PIN diode switches. The 11.25 and 5.625 degree phase bits use a simplified topology of capacitive and inductive elements to achieve their phase shifts [6]. These phase bit topologies are selected due to their broad bandwidth performance and relative insensitivity to process variations. The schematics for these phase bit circuits are shown in Figures 6 and 7.

SiGe PIN diodes (7 × 7 mm) are used for switching functions. Diode biasing is provided through spiral inductors in combination with MIM bypass capacitors. The 180, 90, 45 and 22.5 degree phase bits require two complementary bias inputs of ±1 V. The 11.25 and 5.625 degree phase bits use the same voltages but require a single bias input.

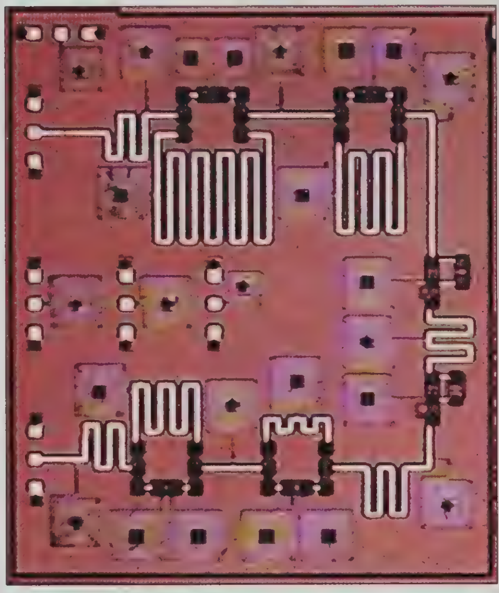


Figure 8(a) · 6-bit phase shifter chip (3.8 × 3.8 mm).

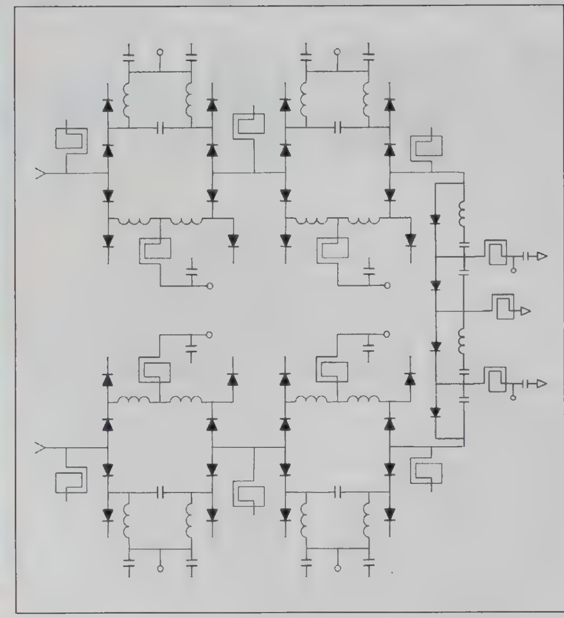


Figure 8(b) · 6-bit phase shifter circuit.

The completed 6-bit phase shifter chip and its associated circuit topology are shown in Figures 8(a) and 8(b). Programmable current sources were used to bias each on-state diode at 2.5 mA. Total current for the phase shifter was 45 mA. Figures 9 through 11 summarize the measured performance of the primary phase states over 5 to 15 GHz, where 7 to 11 GHz is the design band. In the reference state, all phase bits were switched to their high-pass state. At 9 GHz, the measured output 1 dB gain compression is 3 dBm with a TOI of 17 dBm. Post measurement simulations indicate that the overall circuit performance can be improved with additional topside technology improvement leading to improved circuit loss for spiral inductors, transmission lines and input/output (I/O) connections of the phase shifter.

Topside Polyimide Technology

The present IBM SiGe BiCMOS IC process is based on conductive silicon substrates. Therefore, to realize a low loss medium for transmission lines (TRLs), a topside polyimide process has been developed. In the standard IBM 5HP SiGe process, there are five levels of AlCu interconnect metalization. The top-most layer of this metal system is used as a RF ground-plane for the microstrip transmission lines in a polyimide process. Such a ground-plane must have openings to allow connections between the TRLs above and the active and passive devices below.

The first step to create MMICs from the completed Si wafers is to deposit a polyimide layer on top of the ground-plane metalization layer (top metal). After polyimide deposition, vias are etched to contact devices below the ground plane. The polyimide thickness is 15 microns. Figure 12 shows the cross-sectional view of the IBM Si based MMICs using microstrip TRLs on polyimide. As shown in Figure 13, the transmission line loss for a typical 50 ohm microstrip line on polyimide is about 1.20 dB/cm at 10 GHz.

Conclusion

The design and measured performance of several broadband SiGe MMICs including a broadband (1 to 20 GHz) monolithic SPDT switch, a five port transfer switch, and a 6-bit phase shifter, all operating over 7 to 11 GHz, are described. The amplitude and phase control MMIC designs are based on an optimized SiGe PIN diode. The broadband

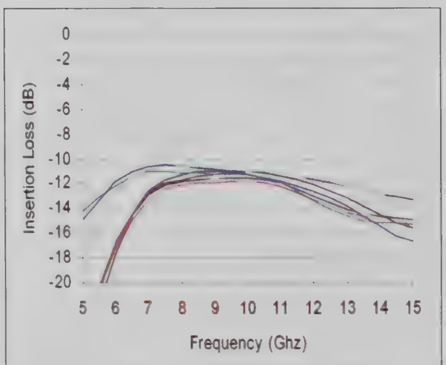


Figure 9 · Measured phase shifter insertion loss.

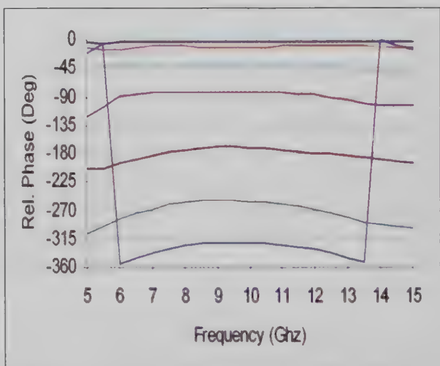


Figure 10 · Measured phase shifter phase performance.

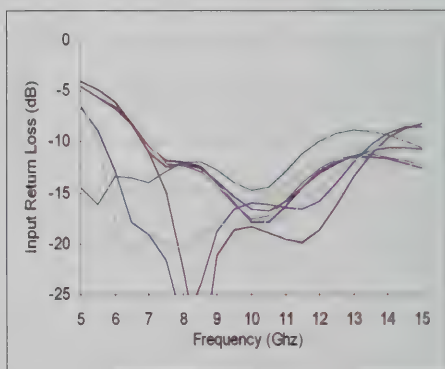


Figure 11 · Measured phase shifter input return loss.

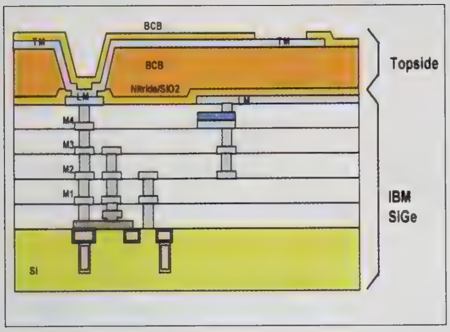


Figure 12 · Cross-sectional view of the topside process.

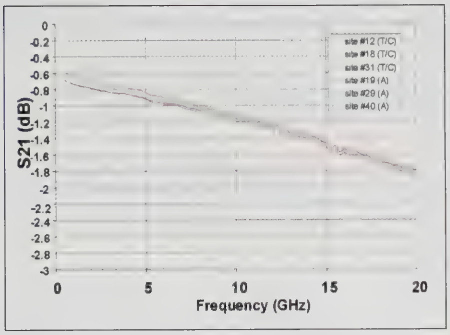


Figure 13 · Loss vs. frequency for 50 ohm, 1 cm TRLs on 15.0 µm polyimide.

(1-20 GHz) resistive bias SPDT switch "ON" arm demonstrates a path-loss of less than 1.3 dB while its "OFF" arm maintains an isolation of greater than 40 dB across 1 to 20 GHz while consuming only 22 mW of DC power. The switching speed, the 1-dB insertion loss compression point and the third order intercept point were found to be <1 ns, 19 dBm and 30.0 dBm, respectively. The transfer switch is a five port design containing 10 PINs and demonstrates a path loss of 1.4 to 2.1 dB across 7 to 11 GHz, the isolation over the same band is >55 dB. The 6-bit phase shifter design successfully demonstrates the feasibility of using SiGe technology for microwave phase control circuit designs. The availability of high performance PIN diodes and other microwave devices including SiGe HBTs, varactors, etc., renders the IBM SiGe technology a new and exciting paradigm for innovative circuit designs suitable for RF and microwave communication systems.

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Author Information

Reza Tayrani received the B.Sc, M.Sc and Ph.D. degrees in electrical engineering from Kent University, Canterbury, England in 1974, 1977 and 1985, respectively. He is currently an Engineering Fellow at Raytheon Microwave Center, Space & Airborne Systems, El Segundo, CA. Dr. Tayrani has over 23 years of experience in the areas of GaAs and SiGe MMICs and their related device and technology development. He has designed and developed many MMICs based on MESFETs, HEMTs, pHEMTs, and HBTs for microwave and millimeter-wave applications. His current areas of interests are high efficiency switching mode monolithic power amplifiers, advanced SiGe MMICs, broadband sampling circuits and miniature switched filters. Dr. Tayrani has published over 48 technical papers and holds 7 patents. He can be reached by e-mail at rtayrani@raytheon.com

Recent Standards Activity: 802.16 WirelessMAN™, 802.15 WPAN and ZigBee

One of the most often heard questions in wireless business is, "What's next?" Among the emerging applications with potential for large markets are various short range wireless systems and citywide wireless access systems. For these application families to reach their potential, a unified set of standards is needed to assure that products manufactured by the various companies are compatible with one another.

We will focus on three specific standards groups: the IEEE 802.15 Wireless Personal Area Network (WPAN) group, the IEEE 802.16 Metropolitan Area Network (WirelessMAN) group and the ZigBee Alliance. Each of these standards groups have active standards development committees, and their recent activities are the subject of this report.

IEEE 802.16 WirelessMAN and WiMAX

The IEEE 802.16 WirelessMAN™ air interface represents the standards effort for wireless broadband Internet access. Initially created to address point-to-multipoint communications in the 28-32 GHz range, the 802.16 group is now working on systems operating as low as 2 GHz. The first standard, covering frequencies from 10 to 66 GHz, was completed in October 2001 and published in April 2002.

Wireless point-to-multipoint services have several key performance issues that are addressed in the standards. These systems operate as base stations with many individual end-user sites. To maintain the desired quality of service, the modulation and coding must maintain high data rates, allow for both downstream and upstream communications, and accommodate variations in system loading, as well as variation in upstream/downstream traffic ratios.

In addition, operation in the tens of GHz range requires line-of-sight communications. The biggest disadvantage is "in the clear" location of base station and user terminal antennas. The main advantage is that single-carrier modulation can be used.

The WirelessMAN standards are now being enhanced as WiMAX (Worldwide Interoperability for Microwave Access). The WiMAX suite of air interface standards will address portable and mobile broadband wireless access, in addition to the fixed systems of WirelessMAN. With bandwidth of up to 75 Mbps, WiMAX uses licensed and unlicensed frequency bands between 2 and 66 GHz.

802.16e, an update to the IEEE standard document, is scheduled for an update in 2005, with the draft completed in the first quarter, followed by committee voting. This version will add additional mobility support.

The next revision 802.16f, is in process in the Network Management (NetMan) Task Group. This work is intended to improve multi-hop functionality, with WiMAX user terminals able to function as repeaters in a mesh network scenario to extend the reach of the network to areas inaccessible to fixed base stations. In part, this is intended to deal with the expected interoperation with cellular and hot spot technologies. 802.16g is intended to deal with efficient handover and improved quality of service.

As indicated by the ongoing work noted above, the initial fixed systems of 802.16 were quickly superceded by proposals to improve network reach and mobility. In addition to mesh network support, coverage can be improved by using frequencies in the lowest part of the available spectrum, as low as 2 GHz. At these frequencies, signal paths are less strict in their line-of-sight requirements. Mobility is being addressed with multicarrier transmission standards (OFDM) that are capable of reliable communications with moving users.

WiMAX and WirelessMAN are generating considerable interest in two areas: as lower-cost alternatives to DSL or cable modem access and as an urban wireless access network operating in a city's main business district and other business centers. The latter application is usually intended to work in conjunction with 802.11 WiFi hot spots and with 3G cellular high-speed data capabilities.

IEEE 802.15 WPAN Standard

Originally, the IEEE 802.15 group was the Bluetooth™ group, but it has evolved to include other short-range Wireless Personal Area Network (WPAN) systems. The initial version, 802.15.1, was adapted from the Bluetooth specification and is fully compatible with Bluetooth 1.1.

As it is now described by the IEEE, "The IEEE 802.15 Working Group proposes two general categories of 802.15, called TG4 (low rate) and TG3 (high rate). The TG4 version provides data speeds of 20 Kbps or 250 Kbps. The TG3 version supports data speeds ranging from 11 Mbps to 55 Mbps. Additional features include the use of up to 254 network devices, dynamic device addressing, support for devices in which latency is critical, full handshaking, security provisions, and power management. There will be 16 channels in the 2.4-GHz band, 10 channels in the 915-MHz band, and one channel in the 868-MHz band."

The 802.15.3 Standard for high data rate services, which continues to be reviewed and enhanced, includes the following features and goals:

- Data rates of 11, 22, 33, 44 and 55 Mbps.
- Quality of Service (QoS) isochronous protocol
- Ad hoc peer-to-peer networking
- Security
- Low power consumption
- Low cost

The higher data rate of this standard is designed to meet the requirements of portable consumer imaging and multimedia applications.

The IEEE 802.15 Task Group 5 is studying mesh networking, determining the necessary mechanisms that must be present in the PHY and MAC layers of WPANs to enable mesh networking, in both full mesh and partial mesh topologies. Mesh networks are useful for entending network coverage without increasing transmit power or receive sensitivity, enhancing reliability with redundant routing, easy network configuration and, ultimately, longer device battery life due to fewer retransmissions.

The IEEE 802.15.3 Study Group 3c, formed in March 2004, is developing a millimeter-wave-based alternative physical layer (PHY) for the existing 802.15.3 WPAN Standard 802.15.3-2003. This mm-Wave WPAN will operate in a band that includes the 57-64 GHz unlicensed band. The millimeter-wave WPAN will allow very high data rate applications such as high-speed internet access, streaming content download (video on demand, HDTV, home theater, etc.), real time streaming and wireless data bus for cable replacement. Optional data rates in excess of 2 Gbps are to be provided.

ZigBee™ Low Cost, Low Data Rate System

In December 2004, the ZigBee Alliance ratified the first ZigBee specification, a major step toward making these systems a reality. ZigBee is an extremely power efficient, cost-effective, low data rate system for monitoring, control and sensing. ZigBee Alliance members can proceed with final development of products and participate in interoperability testing with other member companies. The organization currently has 124 members.

ZigBee is an extension to the IEEE 802.15.4 low data rate standard, adding security, networking and application software to the base standard. Initial applications include industrial and building control and sensors, including HVAC systems, environmental monitoring, security systems, materials handling and manufacturing workflow. The principle advantage is simple system reconfigurability, since nothing is hard-wired. This simplicity extends to both the retrofitting of existing systems and the installation of new systems.

Future applications include home automation where low data is sufficient, such as temperature sensors for environmental controls and medical or security alarm monitoring. Many sensor applications are well-suited for ZigBee, including water level, refrigeration temperature, power quality (brownout) and others. As a data-based system, remote monitoring is simple via any type of wired or wireless access.

802.15.4 and ZigBee products are intended for the lowest possible power consumption, perhaps years of operation from one or two battery cells. This is a key requirement for areas with difficult access.

The next ZigBee Alliance meeting is scheduled for February 28 through March 4, 2005 in San Francisco. See the organization's web site for information: www.zigbee.org

The Impact of Standards

Proprietary systems and protocols certainly exist and have been successful in many cases. In general, however, they are limited to systems from a sole provider, intended for a specific task that does not require interoperability with other equipment from other vendors.

Standards provide an assurance of interoperability among products from different vendors, which is a necessity for systems that will be widely implemented in a variety of configurations. Independent standards organizations such as the IEEE provide the means for developing the necessary standards, while industry-specific groups such as the ZigBee Alliance provide a central clearing house for technical matters like interoperability and for business development discussions, as well.

Electromagnetic Stop-Band Network Improves Class F Amplifier Performance

By Anna N. Rudiakova and Vladimir G. Krizhanovski
Donetsk National University, Radio Physics Department

This article describes an electromagnetic stop-band (ESB) network for high-efficiency class F power amplifiers, providing improved performance in both the pass band and stop band

In a class F power amplifier, producing the required short circuit at even harmonics and the open circuit at the odd harmonics at the active device output can substantially increase efficiency of the power amplifier [1, 2]. With such harmonic tuning, the voltage across the active device output and current through it do not contain harmonics of the same order simultaneously. In practice, it is very difficult to control impedances for an infinite number of harmonics, and the so-called Third-Harmonic Peaking tuning is typically used. In this case, the input impedance of the output network is controlled up to third harmonic. A noticeable increase in efficiency can be achieved if a higher harmonics are also taken into account [3].

Recently, photonic bandgap (PBG) and defected-ground microstrip structures have been proposed as a novel way to accomplish filtering that provides a broad rejection band [4-11]. Such structures can be successfully used as the output networks of high-efficiency power amplifiers. As was suggested in [12], the terminology "electromagnetic stop-band" (ESB) is probably more appropriate than "photonic bandgap." ESB seems to be more commonly used for microwaves, so it is used in this paper.

To achieve high amplifier efficiency, an output network should also provide acceptable matching at the fundamental frequency. So, insertion loss in the pass band should be as small as possible. The weakness of the mentioned PBG (or ESB) structures, when used as amplifier output networks, is their imperfect characteristics in the pass band. This article presents an approach to improve the matching within the pass band.

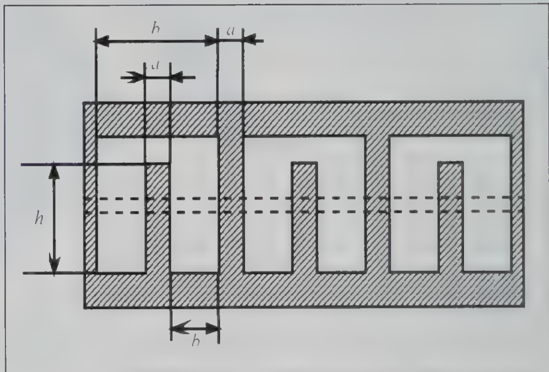

Figure 1 · Proposed double-period ESB structure with improved pass band matching.

Double-Period ESB Structure Design

The top view of the proposed microstrip ESB structure is shown in Figure 1. The ground plane of this ESB contains periodically located Π-shaped holes. The holes sizes are chosen so that structure has one period from one side of strip ($T = a + b$) and two times lower period from another side ($T_i = T/2 = a_i + b_i$). Thus, for given T and b, other sizes can be calculated as:

$$a = a_i = T - b$$

$$b_i = \frac{b - a_i}{2} = b - \frac{T}{2}$$

Simulated scattering parameters of the

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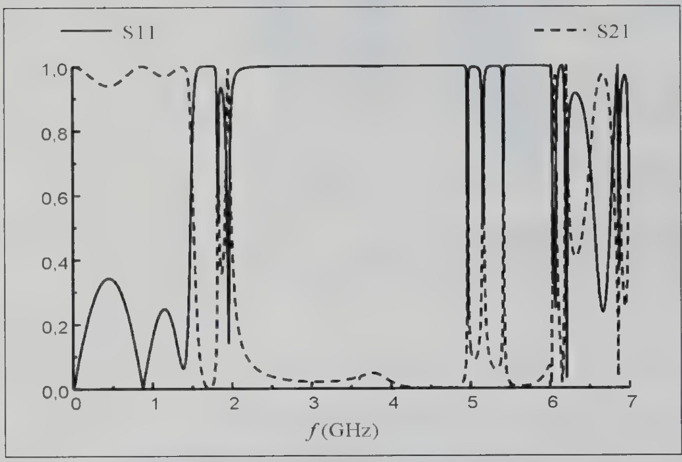

Figure 2 · Scattering parameters of ESB structure under consideration.

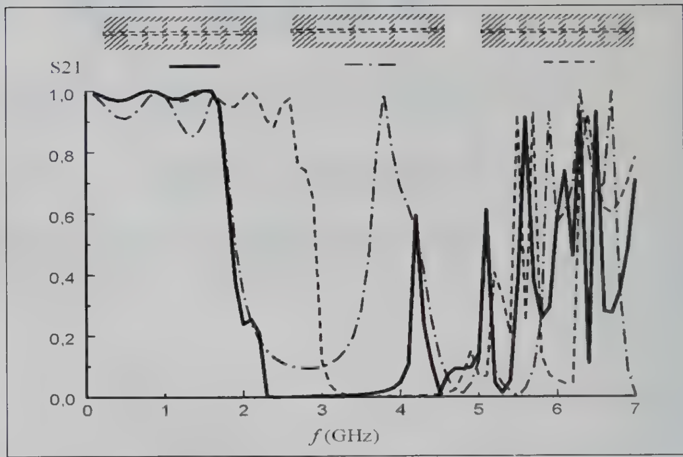

Figure 3 · Insertion loss of ESB structures with $b = 16$ mm.

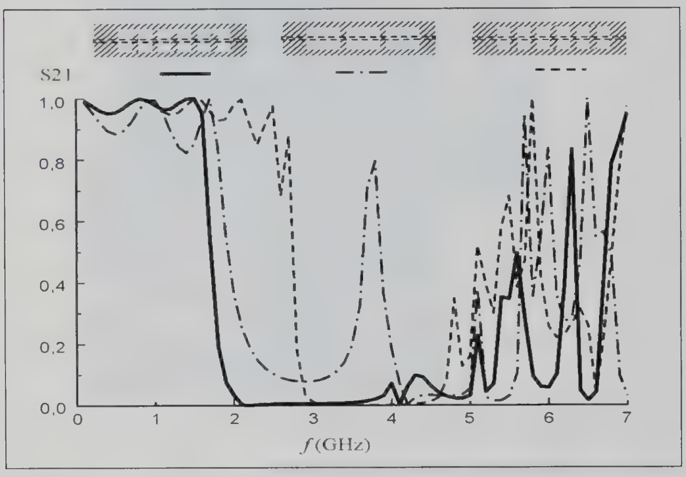

Figure 4 · Insertion loss of ESB structures with $b = 18$ mm.

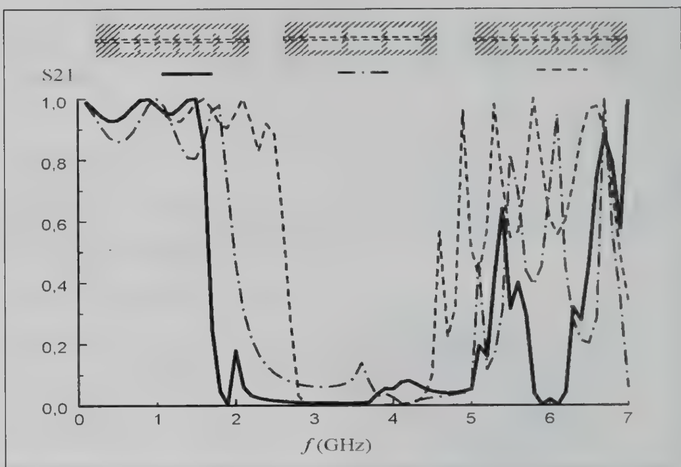

Figure 5 · Insertion loss of ESB structures with $b = 20$ mm.

proposed ESB structure are shown in Figure 2. It can be seen that the three-stage structure has a good match at the fundamental frequency (~850 MHz) and rejects the higher harmonics, up to five.

In order to show the benefits of the proposed double-period ESB, several simulations were conducted for different hole shapes and sizes. The period of structure was the same (T = 24 mm) in all simulations, but with differences in the relationships between the "filled" and "unfilled" regions' sizes.

The simulation results are shown in Figures 3 to 5. For all figures, the solid line means double-period configuration with Π-shaped holes, while dashed and dash-and-dot lines mean rectangular holes in single-period configurations with the periods T_i and T, respectively. Figure 3 relates to the b = 16 mm, and Figures 4 and 5 to the b = 18 mm and b = 20 mm, correspondingly. The figures show that use of Π-shaped holes instead of simple rectangular ones lets us achieve better characteristics for both the pass band and the rejection band.

In the pass band, insertion loss of double-period structure is almost the same as insertion loss of the single-period structure with lower period T_i. It is known that number of ripples in the pass band is one unit less than the number of sections in the finite periodic structure. So, for a six-section structure there are five ripples in the pass band. The amplitude of ripples usually decreases with an increase of their number, that is, with increasing of sections in a structure. But, simply increasing the number of sections leads to a simultaneous increase of the size and height of overall construction. However, as can be seen from Figures 3 to 5, using the proposed double-period structure allows us to obtain low amplitude ripples in the pass band without increasing the number of sections.

In the rejection band, the characteristics of double-period structure become even better than the single-period structure with period T.

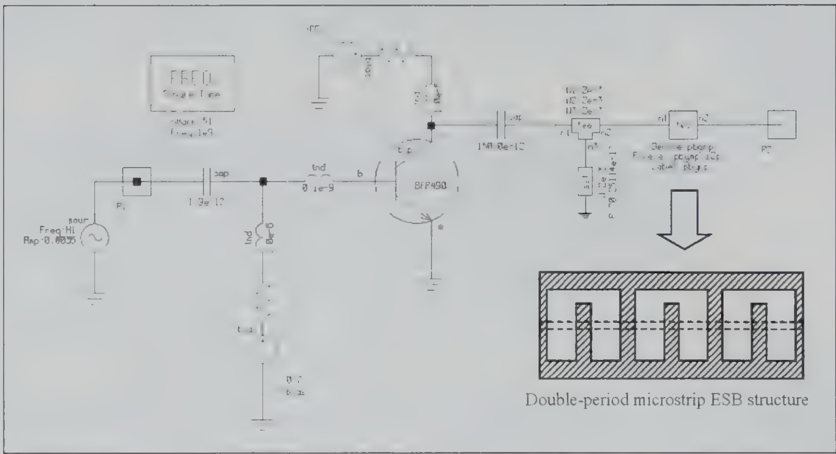

Figure 6 · Equivalent circuit of polyharmonic power amplifier with double-period microstrip structure.

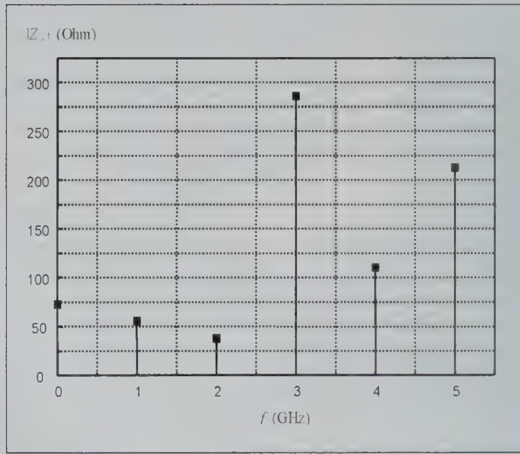

Figure 7 · Magnitude of the output network's impedance versus frequency.

Class-F Power Amplifier Design

Using the proposed double-period microstrip ESB structure, a polyharmonic class-F power amplifier operated at 1 GHz was designed and the three-section ESB was used as the output network. Equivalent circuit of this amplifier is shown in Figure 6.

The microstrip double-period structure was incorporated into the amplifier circuit as a two-port with known S-parameters. The shorted section of original microstrip line was used for tuning of output network's input impedance.

The magnitude of output network's input impedance versus frequency, accounting for the shorted section is shown in Figure 7. Its value at the fundamental frequency is equal to a critical resistance, with respect to maximum power output capability without saturation.

The input impedance magnitudes for the third and fifth harmonics exceed, at some times, the fundamental frequency value (Figure 7). These are mandatory conditions to emphasize the third and fifth harmonics in the output voltage and to achieve target signals' waveforms.

The simulated collector current and collector-emitter voltage waveforms are shown in Figure 8. As can be seen, the collector-emitter voltage has a smoothed bottom, which corresponds to decreased dissipated power and increased efficiency.

The collector efficiency was as high as 78.6% along with PAE equal 78.2%. This achieved result is less—by 4.7%—than the maximally possible 83.3% for the case of fifth-harmonic peaking [3]. This can be explained by a non-zero minimum collector-emitter voltage, which is needed to avoid saturation. The 83.3% value was obtained for the zero minimum voltage case.

The amplifier output power and efficiency versus frequency are shown in Figure 9. One can see that collector efficiency is above 60% within more than 300 MHz frequency band. Over the measured range, the output power varies from 180 mW to a maximum of 280 mW at 960 MHz and exceeds 240 mW over a 200 MHz frequency band.

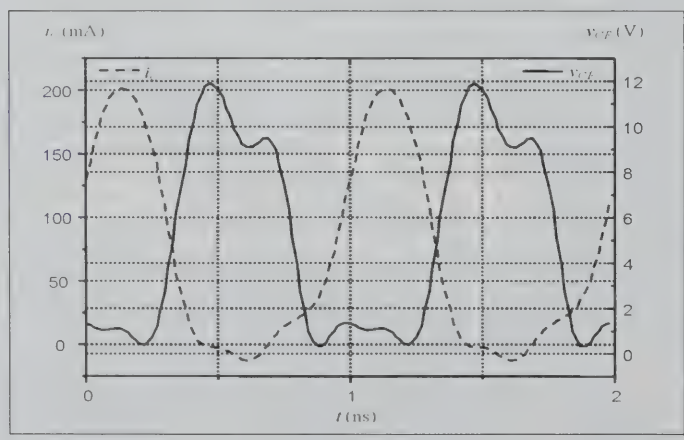

Figure 8 · The simulated collector current and collector-emitter voltage waveforms.

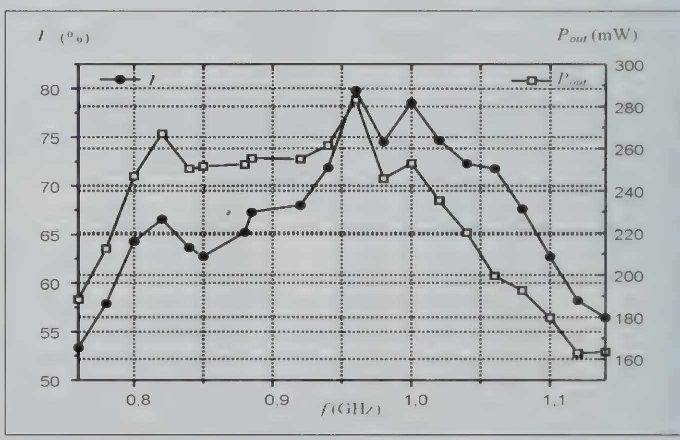

Figure 9 · The simulated amplifier output power and collector efficiency versus frequency.

Conclusion

This paper shows the advantages of using the double-period structures as output networks for polyharmonic power amplifiers. With acceptable characteristics in both the pass band and in the rejection band, the ESB network allows amplifier design with high efficiency over a wide frequency band.

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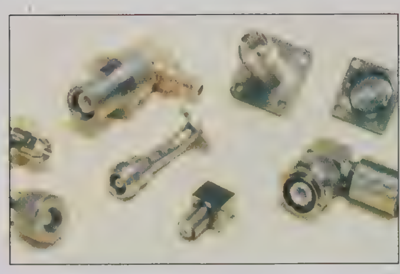
Mini-Circuits



Wi-Fi and FCC Compliant Antenna Connectors

Aviel Electronics designs and manufactures coupling connectors for antenna connections that require compliance with Part 15.203 of the FCC regulations. The connectors range from totally custom to a specific application to a modified version of a standard connector interface to a “standard” reverse polarity interface. Flange mount, crimp and compression cable mounts can be used with uniquely interfaced connector pairs to preclude the possibility of erroneous component mismating. “Coded” pairs can also be fabricated to add further uniqueness within a family of connector components. Materials used in construction include stainless steel, brass or aluminum bodies, beryllium copper contacts with gold, silver, or other popular platings available.

Aviel Electronics
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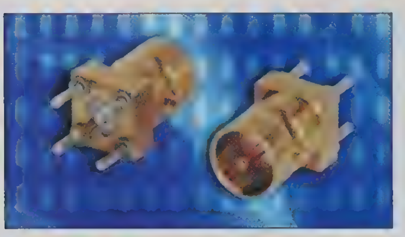

PCB-Mount Jack Connector

Trompeter introduced the UCBJ250S-5-N, a newly designed PCB-mounted jack addition to the company’s M-BNC connector series. The M-BNC Series addresses the issue of reducing size of OEM equipment by enabling a 40% increase in connector density. Matched to telco industry-standard BNC installation tools, this series does not require re-tooling or training for the cable side of the interconnect mated pair and delivers excellent frequency response over an extended bandwidth. This four post design features strong legs for torque capability, as well as a retaining ringless design for improved RF performance. The UCBJ250S-5-N is priced at $2.10 in 1,000 piece quantities.

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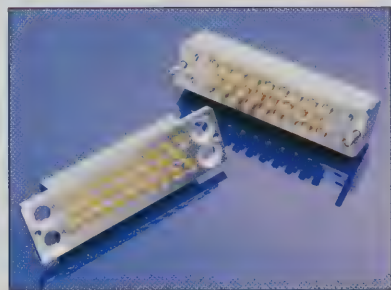

Blindmate Multi-Contact Assemblies

SV Microwave, Inc. provides blindmate connector solutions for rack-and-panel, module-to-module and module-to-motherboard applications. Multiple SMP, BMA, BMMA, BMZ and BZ blindmate connectors can be mounted in standard or custom shells. Fixed mount BMA connectors safely accommodate up to .030 inch (.76 mm) axial and .008 inch (.20 mm) total connector radial misalignment through 12 GHz. The external spring mechanisms of float mount versions provide even higher axial and radial misalignment tolerances. Custom cable assemblies are also available.

SV Microwave, Inc.
Tel: 561-840-1800
www.svmicrowave.com
HFelink 203

High Speed Cable Assemblies

FCI has announced the grant of a license to W. L. Gore & Associates, Inc. to provide high speed cable assemblies using FCI’s AirMax VS® technology. FCI’s AirMax VS terminal block design utilizes a 4 pair per column configuration providing a density of 100 differential pairs per 50 mm of linear board length. The AirMax VS connector allows users to scale systems to greater than 12 Gbps without requiring a platform redesign.

FCI
www.fciconnect.com
W. L. Gore & Associates, Inc.
www.gore.com
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Wireless Product Installation Videos Available On-Line

Times Microwave Systems has recently made available a series of on-line instructional installation videos covering LMR® EZ connectors and LMR accessories including ground kits, weatherproofing kits, hangers and supports for the LMR Wireless Products Line. The videos can be viewed either directly on-line or downloaded for viewing at a later time.

Times Microwave Systems
Tel: 203-949-8424
www.timesmicrowave.com
HFelink 205

Quick Mate Connector Series

RF Connector Division of RF Industries, Inc. announces a QMA series connector similar to the SMA internal configuration, but with a snap-on interface. The connector features a sliding snap-lock mechanism that needs no tooling for mating and unmating. Designed to mate with all QMA jacks, they offer good electrical performance up to 6 GHz. The RQA-5010-C, for RG-58/U and LMR-195 cable, and the RQA-5010-X, for RG-8/X and LMR-240 cable, feature albaloy plated brass bodies, PTFE insulation, spring copper alloy outer contacts and gold plated pins.

RF Industries, Inc.
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Optical Military Cable Assemblies

Molex, Inc. has introduced Optical Military Cable Assemblies for a variety of military, avionics, flight control, mobile tactical field command platforms, Electro Magnetic Interference (EMI) sensitive and security applications. These military style connector solutions are available with fiber optic MIL-T-19504 approved termini, coupled with Commercial Off the Shelf (COTS) cabling and fiber optic connectors. The Optical Military Cable assemblies utilize ruggedized connectors designed for harsh environments. They can be terminated to both single-fiber and ribbon cable and are available in 2- to 29-pin configurations to meet MIL-STD-1560 requirements. The Optical Military Cable Assemblies offer custom lengths for COTS cabling and fiber routing options, including a wide variety developed for use in data and telecom and tactical versions. COTS connector options also include the typical ST, FC, SC, MT, MTP and the unique Molex Array high-density connectors. Cable assembly pricing varies by construction type and length and starts around $400. Short lead-times are available.

Molex, Inc.
www.molex.com
HFelink 207

More Power Added to USB Connector

FCI announces the release of its USB+Power connector system. The USB+Power connectors combine standard USB contacts with additional power contacts to address applications where power requirements exceed the capabilities of standard USB. The configuration provides an additional 3 amps of current-carrying capacity beyond the 1 amp supported by standard USB. Options for 5 V, 12 V or 24 V are available. Pricing for the standard receptacle is $3.52 at 100 pieces.

FCI
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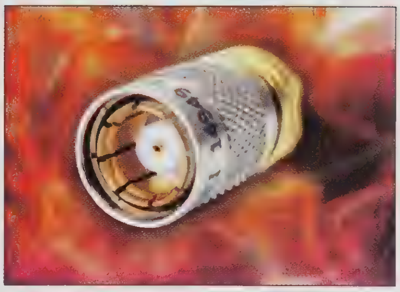

Carrier Class BT-43 Type Posilock Connector

Trompeter announces the newest version of its UPL-143 SMZ Posilock connector, also known as a BT-43. Trompeter's UPL-143 accommodates a broad range of cable and hex-crimp diameters ranging from .178 to .290. These new Posilock connectors are available in straight and 90° configurations. The UPL-143 is priced at $7.26 in 1,000 piece quantities.

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RF Coaxial Connectors and Cable Assemblies

SV Microwave announces a line of high-power coaxial connectors, cable assemblies and components to service the military and commercial industrial markets. Connector series include: SC, HN, 7-16, QDS, LC/LT and EIA, as well as various high-power blindmate connectors and custom, build-to-print designs.

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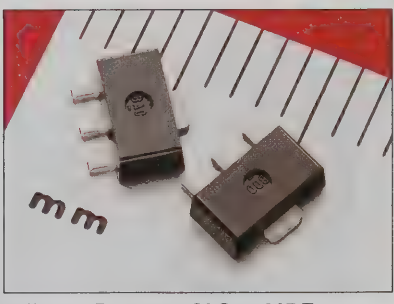

Medium Power SiGe HBT Transistor Amplifiers

California Eastern Laboratories (CEL) announces the availability of two new medium power SiGe HBT transistor amplifiers from NEC. The 800 mW NESG250134 and 1 watt NESG260234 are designed for two-way radio applications. They deliver high gain with high collector efficiency. They can also serve as low distortion amplifiers for return path applications in CATV infrastructure networks. The NESG250134 and NESG260234 are fabricated using NEC's latest UHS2-HV SiGe process. In stock and available now, they're housed in NEC's high-isolation three pin power minimold "34" package.

California Eastern Laboratories
www.cel.com
HFelink 211

Ultra-Efficient RF Power Amplifiers

ParkerVision, Inc. is introducing a lineup of ultra-efficient low cost RF power amplifiers. Extending the science of its patented Direct2Data™ (D2D™) digital RF transceiver technology, the company has developed a digital power amplifier architecture that enables the manufacture of high performance low cost RF power amplifiers in common silicon semiconductors. Additionally, the company announced that its architecture enables models of power amplifiers that inherently perform the function of traditional RF transmitters and totally eliminate the need for traditional transmitter hardware. ParkerVision's power amplifiers are monolithic (single chip) implementations that can be produced in less expensive, high volume silicon semiconductor processes. ParkerVision will offer two families of its power amplifiers which are incorporated in small form-factor packages commonly used for this component.

ParkerVision, Inc.
Tel: 888 690-7110
www.parkervision.com
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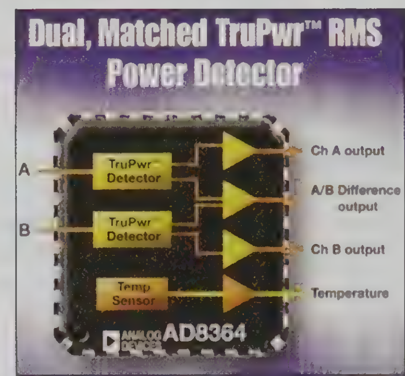

Dual-Channel Power Detector

Analog Devices, Inc. has introduced the industry's first dual-channel radio frequency (RF) root-mean-square (rms) power detector for precision measurement of transmit and receive signals up to 2.7 GHz. The AD8364 is suited for next-generation cellular infrastructure equipment using complex signals with constantly varying peak-to-average ratios. Specific applications include PA (power amplifier) control and linearization, antenna VSWR (voltage standing wave ratio) monitoring, transmitter power control and automatic gain control circuits. The AD8364 provides the following output measurements: two accurately scaled independent outputs for each RF measurement; a difference output measured across the two channel inputs; and a temperature output measured by the on-chip temperature sensor. The AD8364 is available in pre-production quantities, with volume production scheduled for March 2005. The device is priced at $7.85 per unit in 1,000-piece quantities.

Analog Devices, Inc.
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ECM168 Power Amplifier Module

WJ Communications, Inc. announces volume production shipments of its new high efficiency power amp, the ECM168. The ECM168 is the first in a line-up of a series of power amplifiers primarily targeted towards the PAS/PHS wireless infrastructure markets. The ECM168 is a 1.9 GHz high efficiency power amplifier module utilizing InGaP HBT process technology. Key features include: 33.5 dBm output power, a single 10-12 V supply, 33 dB typical gain and excellent ACPR2 at 600 kHz offset. The device operates over a frequency range of 1880-1920 MHz. No negative voltage is required and the efficiency is in excess of 20%. The ECM168 is housed in a low cost, flange mount package measuring only 29 × 13 × 4 mm. Fully assembled device samples are available now and can be requested directly from the WJ web site.

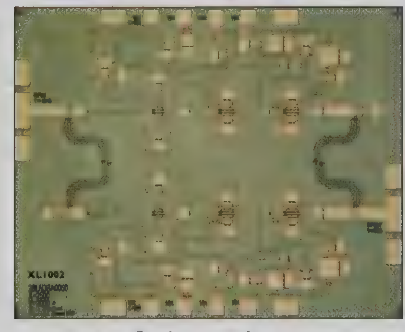
WJ Communications, Inc.
www.wj.com
HFelink 214

Wideband Cascadeable Gain Block

Hittite Microwave Corporation announces the release of a new SiGe HBT Gain Block MMIC amplifier covering DC to 5 GHz. The high linearity HMC482ST89 SiGe HBT Gain Block is fully matched to 50 ohms, provides 19 dB of gain and can be used as a cascadeable gain stage in various RF and IF applications. With +22 dBm of output P1dB and +36 dBm of output IP3 at 1 GHz, the HMC482ST89 can also be used as an LO buffer amplifier or as a PA pre-driver. This MMIC amplifier consumes only 110 mA from a sin-

gle positive supply of +6 V and requires no external matching components. It is housed in a SOT-89 surface mount package.

Hittite Microwave Corporation
Tel: 978-250-3343
www.hittite.com
HFelink 215



GaAs MMIC Amplifier

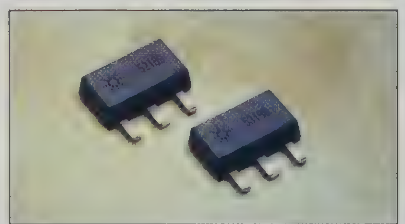
Mimix Broadband, Inc. has introduced a gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) three stage low noise amplifier that covers the 20 to 36 GHz frequency bands. The low noise amplifier, identified as XL1002, has a small signal gain of 23 dB with a noise figure of 2.5 dB across the band. The XL1002 includes simple, single supply bias with no need for negative voltages or active bias circuits and offers excellent input and output match due to its balanced design. It is well suited for wireless communications applications such as millimeter-wave point-to-point radio, local multipoint distribution services (LMDS) and SATCOM. Engineering samples are available today from stock, along with production quantities.

Mimix Broadband, Inc.
www.mimixbroadband.com
HFeLink 216

Multi-Channel Easy-Interface Transmitter IC

Analog Devices, Inc. has introduced the ADF7901, a low-power OOK/FSK UHF transmitter designed for use in RF remote control applications. The monolithic transmitter IC delivers +12 dBm of output power at 384 MHz, while drawing only 26 mA of current. Using a fractional-N PLL and fully integrated VCO, the transmitter provides 369.5 to 395.9 MHz frequency operation. The device is also capable of frequency shift keying (FSK) modulation on eight different channels, selectable by three external control lines. OOK modulation can be performed on the ADF7901 by modulating the PA control line. The on-chip VCO operates at two times the output frequency, and the divide by two at the output of the VCO reduces the amount of PA feedthrough. The FSK_ADJ and ASK_ADJ resistors can be adjusted in the system to optimize output power for each modulation scheme. An additional 1.5 dB of output power is provided for the lower bank of channels to adjust for antenna performance. The CE line allows the transmitter to be powered down completely, and in this mode the leakage current is typically only 0.1 µA. The ADF7901 is available now, priced at $1.89 per unit in quantities of 1,000.

Analog Devices
Tel: 800-ANALOGD
www.analog.com
HFelink 217



Low-Cost SOT-89 High-Linearity E-pHEMT FETs

Agilent Technologies, Inc. has announced two additional members of its family of high-linearity E-pHEMT FETs in the industry-standard 4.5 × 4.1 × 1.5 mm SOT-89 surface-mount package. By using an industry-standard package, Agilent's new ATF-52189, ATF-53189 and previously introduced ATF-50189 single-voltage E-pHEMT FETs simplify upgrading 50 MHz to 6 GHz base stations to higher-channel capacity. The devices are designed for use in the transmitter power amplifiers and receiver low-noise amplifiers in cellular and PCS base stations, low-earth-orbit satellite systems, terrestrial multichannel multipoint distribution systems (MMDSs) and other communications applications operating from 450 MHz to 6 GHz. At 2 GHz, the ATF-52189 has 42 dBm third-order output intercept point (OIP3), typical 27 dBm linear output power (P_{1dB}), 16 dB gain and 55-percent power-added efficiency (PAE), combined with a 1.5 dB noise figure. Typical operating bias is 4.5 V at 200 mA. The ATF-53189 features a lower 0.85 dB noise figure, combined with a 40 dBm OIP3, 23 dBm P_{1dB}, 15.5 dB gain and 46-percent PAE. Typical operating bias is 4.0 V at 135 mA. These devices are supplied in lead-free packaging with a moisture sensitivity level-1 (MSL1) rating. The Agilent ATF-52189 is priced at $2.56 each and the ATF-53189 at $2.11 each, in moderate volumes.

Agilent Technologies
Tel: 800-235-0312
www.agilent.com/view/rf
HFeLink 218

20 Watt CW Limiter

Planar Monolithics Industries offers Model Number LM-20M80M-10-20W, a high power limiter that operates from 25 to 80 MHz (other frequencies are also available). The output limiting is +15 dBm maximum, and the limiter can handle an input power level of 20 watts, with an insertion loss of 0.5 dB maximum, a typical VSWR of 1.5:1 and a msec recovery time, all in a small connectorized package, 1.0" × 1.0" × 0.40".

Planar Monolithics Industries, Inc.
Tel: 301-631-1579
www.planarmonolithics.com
HFeLink 219

Power Amplifier Module

An advanced front-end power amplifier module from Freescale Semiconductor, Inc., the MMM6015, can reduce the amount of board space needed by more than 40 percent versus the current generation of handset PAs. The MMM6015 design integrates the power amplification, power control, low-pass filtering and antenna switching functions, while enhancing the battery life of the handset. Targeted for a wide variety of next generation GSM/GPRS phones, the MMM6015 is a front-end power amplifier module for quad-, tri- and dual-band GSM handset applications across the 850, 900, 1800 and 1900 MHz bands. The small module measures 6 × 8 × 1.15 mm, and includes anti-saturation technology to prevent switching transients when the battery voltage sags from a low battery. The MMM6015 can be incorporated into a cellular platform or designed in as a stand alone component. The suggested resale price is $4.50 at 10k quantities.

Freescale Semiconductor
www.freescale.com
HFeLink 220

100 Watt Fixed Attenuators

Mini-Circuits' new 50 ohm, 40 dB, 100 watt fixed attenuators are excellent for testing high power components used in communication systems. These attenuators are ideal when testing high power amplifiers while using low power test equipment, and with 40 dB attenuation they can also be used as a termination for high power amplifiers. The new BW-40N100W DC to 4 GHz attenuators are a useful addition to a testing facility. Pricing is $249.95 each, qty. 1-9.

Mini-Circuits
Tel: 718-934-4500
www.minicircuits.com/BW-40N100W.pdf
HFeLink 221

Featured Product Coverage in Upcoming Issues:

March:	MMIC Amplifiers, Frequency Synthesizers
April:	Resistive Products, Tools & Accessories
May:	Signal Analyzers, High Power Components

A Guide to Microwave Diode Package Styles and Their Performance

By K. R. Philpot
Microsemi Microwave/Lowell

This article provides a review of microwave diode packages, with attention to the electrical and thermal performance characteristics that affect each type's suitability for particular applications

Few subjects cause more problems and confusion for users of microwave diodes than the effects of the diode package. Although they are required for most applications, packages always limit the performance of the circuit design, sometimes in unexpected ways. This paper will discuss the different types of packages available, the attributes of each and the effects one might expect when used in some common circuit applications.

Packages are a necessary evil. In a perfect world, all designs would make use of the unpackaged die, installed eutecticly and wire bonded into the circuit. However, microwave diode packages afford protection for the die, ease of handling and a means of efficient automated circuit assembly. Any discussion of microwave diode packages must start with an understanding of the detrimental attributes that packages bring.

Package Parasitics

Parasitics are unwanted electrical and mechanical attributes that result from the physical construction of the package. Package types have various combinations of parasitics, which limit circuit performance in different ways. The right choice of packages is always a compromise, often the lesser of several evils. Let's examine the different microwave diode package parasitics:

Series Inductance (Lp): Because any diode package has exterior terminations that must be connected to the die inside, there will always be an inductance associated with the wire or conductor used to accomplish this. The best high frequency microwave packages will have values as low as 150 pH. The worst can have over 2,000 pH, which is like putting a large value of inductive reactance in the worst possible place in your circuit—directly in series with the diode!

Shunt Capacitance (Cp): All packages are constructed using conductive metals and insulating materials with a particular dielectric constant. As we know, conductors separated by dielectric material create a capacitor. Values for a package's parasitic capacitance vary from under 100 fF to over 1,000 fF. This capacitor is also in the worst possible place in your circuit—directly across the terminals of the diode!

Series Resistance (Rs): The conductors used to connect the die to the exterior of the package are usually gold wire or at least gold plated. Although gold is a very good conductor, even small magnitudes of resistance can affect microwave circuit performance. A 0.1 ohm value of resistance in series with the device can result in measurable reduction in switch isolation or an increase in VCO phase noise.

Thermal Resistance (θj): Devices that handle power, such as PIN diodes or SRDs (step recovery diodes), need to have a thermal shunt to ground in order to dissipate excess power in the form of heat. If power cannot be dissipated, the junction temperature of the device can rise to the point of destruction. Some packages are designed to have excellent thermal properties with thermal resistance values as low as 10 degrees C/W. Others have values as high as hundreds of degrees C/W.

Pkg. Type	Lp	Cp	Rs	θj	Cost	Max Freq.	Hermetic	Comments
Ceramic	Excellent	Excellent	Excellent	Excellent	High	18 GHz	Yes	All products available
MELF	Good	Fair	Excellent	Very Good	Moderate	2 GHz	Yes	Only select PIN diodes available
MMSM	Very Good	Very Good	Good	Very Good	Low	8 GHz	No	Only select PINs and varactors
EPSM	Good	Good	Good	Good	Moderate	6 GHz	No	All products available
Glass Axial	Fair	Good	Good	Poor	Moderate	1.5 GHz	Yes	Many products available
Plastic	Poor	Fair	Fair	Poor	Low	2 GHz	No	Only select PINs, varactors & Schottkys
Stripline	Good	Good	Good	Fair	Moderate	8 GHz	Yes or No	All products available

Table 1 · Microwave diode package comparisons.

Circuit Implications of Parasitics

As a general rule PIN diode switch applications demand the lowest possible parasitic capacitance. This value directly limits the isolation that can be achieved in a series design. Additionally, low values of thermal resistance are highly desirable in order not to compromise the power handling characteristics of the device.

PIN diode limiters also require packages which have low thermal resistance, but it is also imperative to limit parasitic inductance.

Schottky diodes used as mixers or detectors usually do not have to dissipate much power, so package thermal resistance is not usually a concern. Minimizing parasitic inductance and capacitance are important, but not critical as in PIN diode applications.

Varactor diodes used in voltage controlled oscillators (VCOs) demand the lowest package parasitic inductance. This value will directly affect the maximum frequency which can be achieved. Package parasitic capacitance will limit the bandwidth (tuning range) and tuning linearity of the VCO. Because VCOs do not require power to be dissipated in the varactor, package thermal resistance is usually not important.

Comb generators and harmonic generators using SRDs and VGVs (harmonic generator varactors)

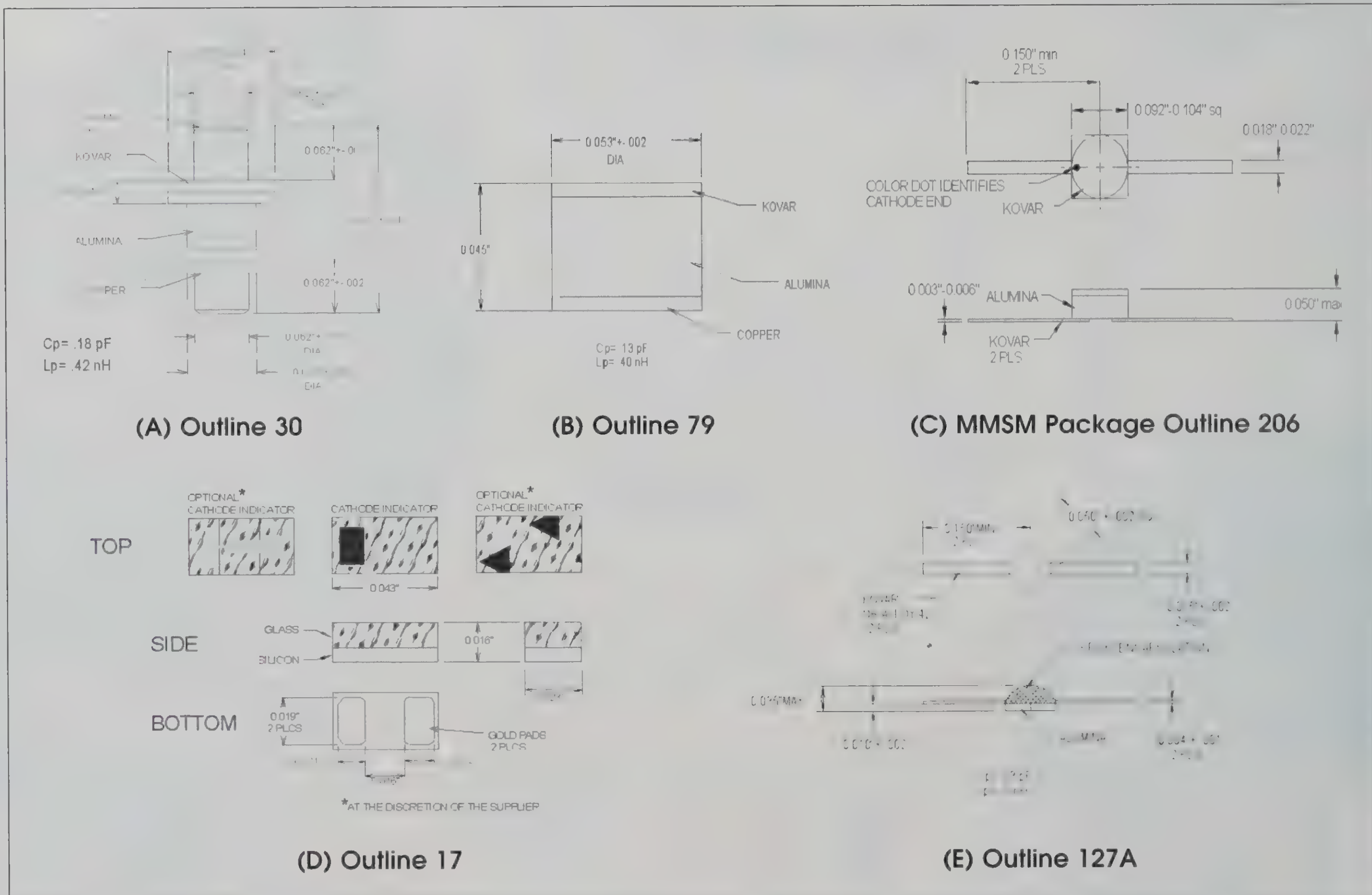
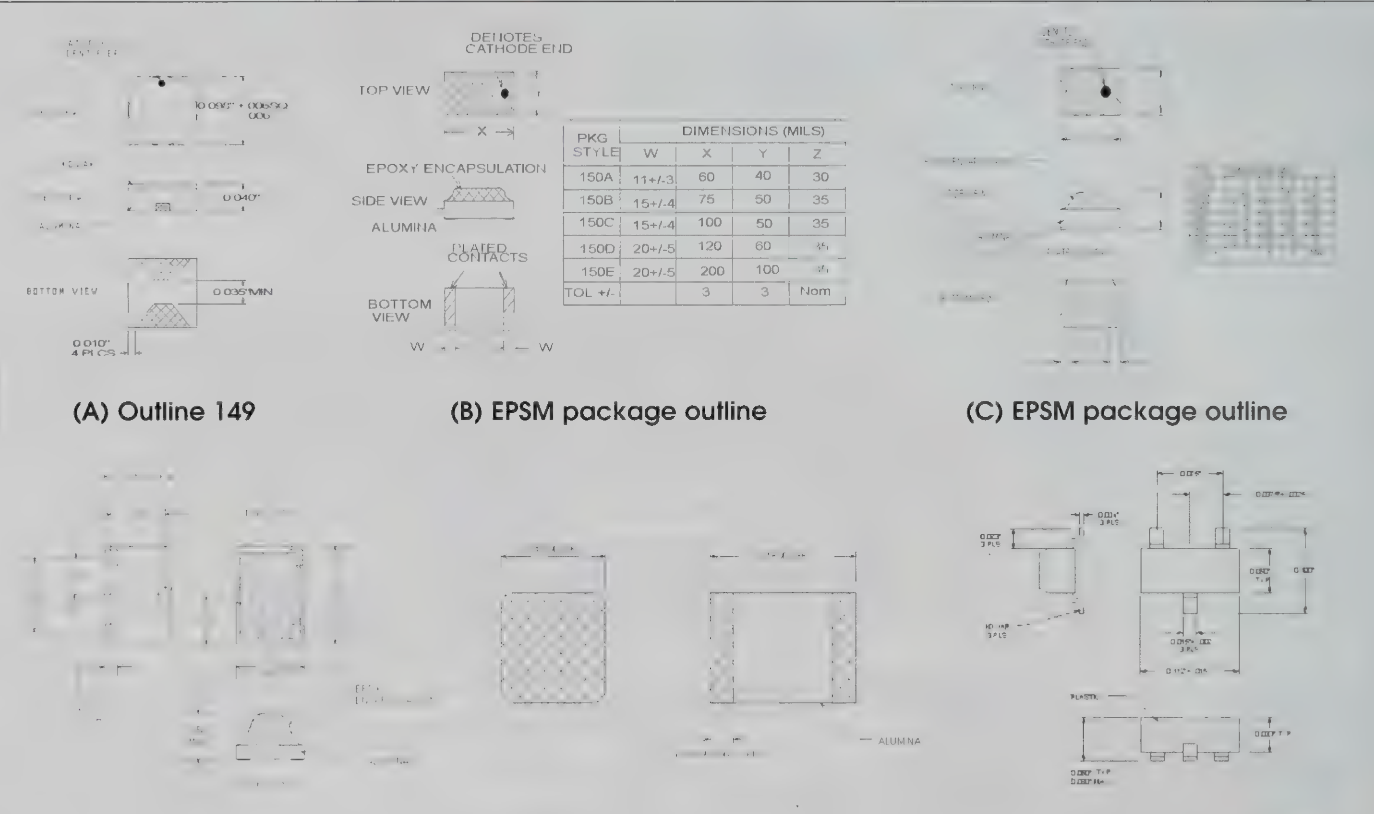


Figure 1 · Microwave packages.



PKG STYLE	DIMENSIONS (MILS)			
	W	X	Y	Z
150A	11+/-3	60	40	30
150B	15+/-4	75	50	35
150C	15+/-4	100	50	35
150D	20+/-5	120	60	[illegible]
150E	20+/-5	200	100	[illegible]
TOL +/-		3	3	Nom

(A) Outline 149 (B) EPSM package outline (C) EPSM package outline

(D) EPSM package outline (E) M1 MELF outline (F) SOT-23 package outline

Figure 2 · Surface mount packages.

demand the lowest possible package thermal resistance due to the large power dissipations in these applications. Package parasitic inductance and capacitance can often be tuned out provided the magnitude is not too great.

Package Categories

In general terms, packages can be grouped broadly into three categories: Microwave, Surface Mount and Through-Hole. Some package types such as Microwave Monolithic Surface Mount (MMSM™) belong in more than one category. Let's discuss each category and look at some examples. Refer to Table 1 for some comparisons between package types.

Microwave Packages

There are three package types which can be used at microwave frequencies above 6 GHz.

Ceramic packages are the best performing microwave package styles available. They are hermetic and the type of choice for military and space applications. They are also the most expensive. They combine low parasitic inductance, low parasitic capacitance and can have superior thermal resistance characteristics as well. Most products are available in ceramic packages. Outline 30 and 79 are good examples (Figures 1A and 1B).

MMSM packages combine the attributes of excellent microwave performance, surface mount convenience and economy pricing, but only select products are available in this outline. Consult the factory for details. Figure 1C shows the MMSM package outline (206).

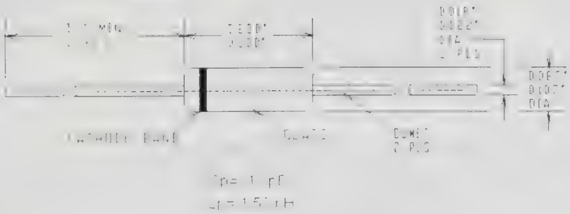
Stripline packages for microwave are usually also ceramic and can be completely hermetic or have epoxy encapsulation. They combine low parasitic inductance, low parasitic capacitance and are designed specifically for stripline or microstrip construction. They can, however, have high thermal resistance and are not the best choice for applications which will result in high device dissipation. Outline 17 (Figure 1D) is hermetic, and outline 127A (Figure 1E) is epoxy encapsulated.

Surface Mount

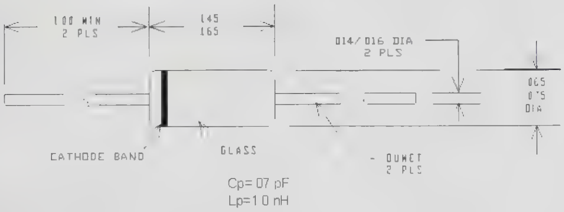
There are five types that can be used for surface mount applications. Once again some fall into more than one category: MMSM, ceramic, EPSM, MELF and plastic (SOT-23).

MMSM outline 206 was discussed under microwave packages above (Figure 1C).

Ceramic surface mount packages combine all the excellent attributes of ceramic microwave packages with the ease of surface mount assembly



(A) Outline 11



(B) Outline 15

Figure 3 · Through-hole packages.

compatibility. Most products are available in this type. Figure 2A shows a good example/outline of 149.

Enhanced Performance Surface Mount (EPSM™) packages offer consistent performance for applications up to 6 GHz. Both parasitic inductance and parasitic capacitance are very low compared to conventional plastic injection molded surface mount packages. Thermal resistance is moderate but is also superior to plastic. Additionally there are a wide range of outlines from which to choose, and most products offered are available in EPSM. Figures 2B, 2C and 2D show some common EPSM outlines.

Metal Electrode Leadless Faced (MELF) packages are specially designed for PIN diodes. They have low values of parasitic inductance but high values of parasitic capacitance. They are suitable for frequencies under 2 GHz and have very low thermal resistance, making them suitable for power applications. Only select PIN diodes are available in MELF packages. Figure 2E shows the M1 MELF outline.

Plastic SOT-23 packaged devices are rugged economical packages suitable for low power applications with frequencies up to 2 GHz. They have moderately high levels of all parasitics but are ideal for less critical higher volume commercial use. Figure 2F shows the SOT-23 package.

Through-Hole

Glass axial packaged diodes have been around for many years and are still popular today for UHF frequencies and below. Their hermeticity and proven environmental design are favorites for military requirements. They have very high thermal resistance which makes them unsuitable for high power applications. Figure 3 shows two common glass axial package outlines.

Author Information

Kenneth R. Philpot is presently Director of Applications at Microsemi Lowell (Massachusetts) and has been a microwave circuit designer since 1967. Prior to his employment with Microsemi Corp, he held senior engineering and management positions with Lockheed Martin Microwave, L3 Communications, Loral Corporation, GHZ Devices and Frequency Sources, Inc. Readers may contact Ken Philpot directly at (978) 442-5616 or by e-mail at kphilpot@microsemi.com

Using Advanced EDA Models for Simulation of Circuits and Systems

By Gary Breed
Editorial Director

Computer simulation of RF, microwave and optical circuits and systems is only as good as the models that define components, interconnections, propagation, modulation and system impairments

Electronic design automation (EDA) tools have become indispensible for designers of all electronic products. The increased complexity of circuits and systems, combined with business demands for short development times, requires the power of a computer to bring an engineer's creative idea to fruition.

Since the first calculations were programmed into early computers, the main issue has been the ability of the mathematical representation to replicate reality. Despite truly astonishing progress in model development, this issue is still paramount—the ability to create better models and algorithms never seems to catch up with the accuracy demands of new applications.

A Little History

Since this is our tutorial column for this issue, it is useful to review the development of mathematical analysis and modeling of RF, microwave and other high-speed/high-frequency circuits and systems.

Modeling began with AC circuit theory, the familiar equations that describe the behavior of passive components: ideal inductors, capacitors and resistors. Ideal amplifiers (operational amplifiers) and diodes allowed simple active circuits to be added to the calculations. Even today, this collection of ideal circuit models provides a surprisingly good starting point for low-frequency design. Of course, this is not the case at higher frequencies of operation—the basis of classic RF/microwave design.

All real-world circuits exhibit frequency-dependent behavior. The ideal components mentioned above have first-order terms (the familiar $2\pi f$) for frequency but do not include additional factors that come into play at higher frequencies. The old saying is true: at high frequency, all components are simultaneously resistors, capacitors and inductors (and antennas), and all wires are transmission lines.

Today's advanced models are the result of greater precision in the representation of these high-frequency effects.

Demand Factors

The demand for improved models has been driven by several factors:

- Circuits operating at higher frequencies, as well as broader bandwidths.
- Dramatic increases in available computing power—early computers could not handle a complex model, but that has changed.
- More complex communication systems that require automated design processes to manage their development.
- Marketplace and management demands for faster product development, which also needs automated design to keep pace.
- Functional design is often combined with manufacturing design for monolithic ICs and various modular technologies like multi-chip modules (MCMs), system-on-chip (SoC) and low-temperature co-fired ceramic (LTCC) fabrication. These all require a high degree of process automation.
- Finally, growth in wireless and high-speed digital systems has required increased productivity from engineers in those specialty areas.

Now that we have established the general scope of EDA models and the factors driving their development, let's examine some of the specific characteristics of component models:

Parasitics—All advanced models include greater detail in the inclusion of parasitic capacitance and inductance. Where earlier models lumped several parasitic mechanisms into a single element of an equivalent circuit, an advanced model represents each physical source of parasitic reactance separately, a more complex, but more accurate, representation.

Frequency-dependence—Describing this area of modeling could fill books! Some of the frequency-dependent characteristics that are included in modeling include measurement-based data derived from wafer probing or de-embedded test fixtures. When possible, electromagnetic (EM) simulation is used to analyze the physical construction of components and create a behavioral model that can be used like an analytical model.

Real-world assembly—Because components are ultimately assembled onto a substrate (board, module or semiconductor), the interconnections between the components and the larger assembly must be included in the model. The models can be developed from measurements or through EM simulation. In either case, the modeled characteristics must accurately represent the specified construction, including such things as pad size, process-specific dielectric and metallization parameters, and even the nature of other components and objects in proximity.

Brand-specific models—This area of advanced modeling is experiencing a resurgence of interest as previously-developed models for a company's product line are proven to be insufficient for today's EDA environment. New model families are regularly announced by active and passive component suppliers.

System-Level Models

Every electronic product performs a function, and those functions are part of the overall design and simulation process. In the case of a wireless communication system, there are several types of models that must be accurately represented in the simulation of the entire signal path. These include:

Noise—Signal-to-noise ratio determines the reliability of all communications systems. System simulations must include accurate modeling of the noise added by both active and passive components, including both amplitude and spectral characteristics.

Time-domain behavior—Complex modulation can be degraded by time-domain variations, including excessive group delay and reflections. Models of subsystems (e.g., filters) can be developed from circuit simulation or measurements, as appropriate. Some of these are manufactured components such as SAW filters and integrated multi-function modules, and their manufacturers must be able to provide accurate behavioral models that permit accurate system-level simulation.

Non-linear models—Distortion caused by non-linear behavior is often poorly modeled, resulting in unexpectedly poor performance when a circuit is constructed and tested. A "perfect" non-linear model would include both DC and dynamic behavior—and not just in the main signal path. The response to signals impinging on the output of the device should be part of the model, to allow simulaltion of interference from external sources such as co-located transmitters! Non-linear performance of passive components is a growing area of interest, and no longer limited to the high-power portions of the system.

Electromagnetic Modeling

Electromagnetic modeling remains an extremely active area in university research, as well as practical engineering. It may be the one area of simulation that has benefitted the most from the availability of cheap computing power, because of the total number of individual computations needed for finite element or finite time difference calculations.

Because EM simulation uses a physical representation of a structure, its results can be correlated to the real world more easily than an equivalent circuit mathematical model. But solving the various derivations of Maxwell's equations is a big job, which is the price of greater simulation accuracy.

EM simulation is good enough, in some cases, to replace measured data in the development of lumped element equivalent circuit models, at least over a selected range of frequencies. Also, the size of EM problems that can be handled has grown—with enough computing power, a completed circuit board can now be modeled to evaluate its radiated emission performance and its susceptibility to incident fields.

Propagation Modeling

Although generally considered to be a separate problem than circuit/system simulation, it is appropriate to note the evolution of propagation models from statistically-based models to more accurate methods. New propagation models, while not yet perfect, include improved techniques for ray-tracing, dispersion and reflection, in environments that have multiple objects with different conductive or dielectric properties.

For anything but free-space (or nearly so) communications, the best propagation models are still measurement-based, using *in situ* test transmitters and receivers to evaluate specific sites and environments. These "good approximations" are valuable, although the randomness and complexity of the real world probably precludes a more precise simulation.

Tuning Fork Crystals

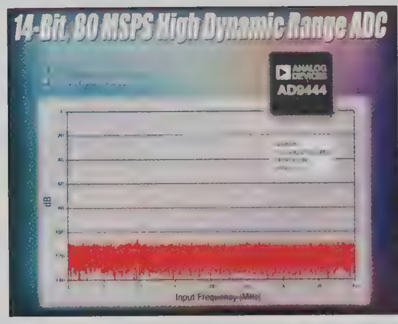
Raltron Electronics Corp. introduces its smallest tuning fork crystal line, the RT Series. The main product in the series is RT4115 which has a compact 4.1 × 1.5 × 0.85 mm housing, high shock and vibration performance and is lead-free. Its height of 0.85 mm max is ideal for low profile applications. Raltron also offers the RT3215 with dimensions 3.2 × 1.5 × 0.85 mm. Popular applications include cell phone handsets, PDAs, clock timers, wireless devices and radio communication equipment. The RT Series is supplied with a standard ±20 ppm frequency tolerance at +25°C, an operating temperature range of –40°C to +85°C, a low resistance (ESR) of 80 ohms max and 12.5 pF load capacitance. Delivery is six to eight weeks with prices starting at $0.50 each in quantities of 10,000 pieces.

Raltron Electronics Corp.
Tel: 305-593-6033
www.raltron.com
HFeLink 222

1.5 and 3.0 GHz Attenuators

Elcom Systems, Inc. has announced the availability of two series of miniature 50 ohm coaxial attenuators for use from DC to 1.5 GHz and DC to 3.0 GHz. The 1.5 GHz attenuators are available with BNC, TNC, N or SMA connectors and the 3.0 GHz attenuators are available with SMA, SMB, BNC and TNC connectors, both in 1 dB steps from 1 to 10 dB, and 2 dB steps to 20 dB. The 1.5 GHz attenuators have 0.5 dB accuracy to 1.0 GHz, and 1 dB to 1.5 GHz. VXWR is 1.2:1 nominal, 1.25:1 maximum. The 3.0 GHz attenuators have 0.5 dB accuracy to 2.5 GHz, and 1 dB to 3.0 GHz. VXWR is 1.2:1 nominal, 1.70:1 maximum. Both attenuators have silver, gold or nickel plated connectors. Resistor networks are mounted in Mil spec plated housings. Prices for 1.5 GHz attenuators start at $9.50 each, in small quantities. Prices for 3.0 GHz attenuators start at $11.50 each, in small quantities. Delivery is stock to 30 days ARO.

Elcom Systems, Inc.
Tel: 561-883-1945
www.elcomsystems.com
HFeLink 223



14-Bit ADC has Low SFDR

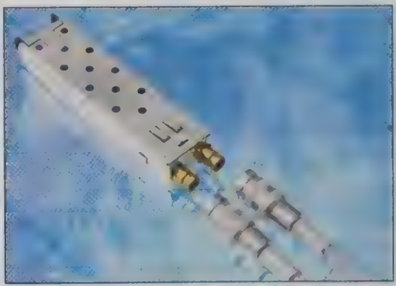
Analog Devices, Inc. has introduced a 14-bit, 80-MSPS (mega-samples-per-second) analog-to-digital converter (ADC) that offers high spurious-free dynamic range (SFDR). The AD9444 provides a typical SNR of 73.1 dB and SFDR of 97 dBc with a 70 MHz input. Optimized for wireless base station applications, its high SFDR makes the AD9444 well-suited to test equipment, wireless broadband and high-end data acquisition systems, and it expands the dynamic range of wireless base station receivers. The AD9444 provides high accuracy, with typical differential nonlinearity (DNL) of ±0.4 LSB, integral nonlinearity (INL) of ±0.6 LSB and power dissipation of 1.2 W. The ADC also features parallel low-voltage differential signaling (LVDS) outputs, including an output clock, simplifying the interface to digital down-converters and reducing the potential for digital noise coupling into the ADC core.

Analog Devices, Inc.
Tel: 800-ANALOGD
www.analog.com
HFeLink 224

Solid State Switch Matrix with Ethernet Interface

Dow-Key Microwave's newest product, a solid state switch matrix with Ethernet control interface, performs from 800 to 2500 MHz and is available in full fan-out configurations from 6 × 6 to 12 × 12. All inputs are outfitted with high linearity amplifiers. While the 3202 Switch Matrix is designed for signal routing applications, it can also be utilized as a building block for numerous ATE applications. Each unit is equipped with a Windows-based PC computer and front-panel touch screen for manual override and is housed in a low profile 3U rack mountable chassis. System impedance is 50 ohms.

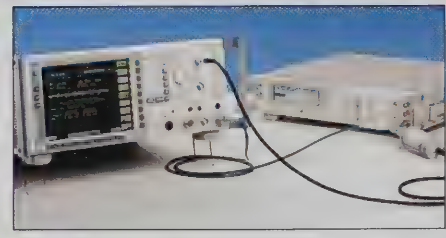
Dow-Key Microwave
Tel: 805-650-0260
www.dowkey.com
HFeLink 225



Electrical SFP Transceiver

The new SFP-155E electrical transceiver from ITT Industries, Cannon delivers full duplex STM-1 electrical (155 Mbit/s) SDH transport over coaxial cables. Typical applications include Next Generation SDH Add/Drop multiplexers, Optical Edge devices, MSPP and switching systems. The hot pluggable module is fully interchangeable with STM-1 optical SFP modules. Additionally, a single card can now support both optical and electrical STM-1 inter-

Calibration and Measuring Receiver



Rohde & Schwarz has introduced the FSMR Measuring Receiver, a single-instrument solution for calibrating all key parameters of signal generators and fixed and variable attenuators. The FSMR provides the functions and precision required to perform signal generator and attenuator calibration without additional hardware or software. It combines a level calibrator; AM, FM, and PM modulation analyzers; an audio analyzer with THD and SINAD capability; an RF power meter; and comprehensive spectrum analyzer functions in one instrument. It is available in frequency ranges from 20 Hz to 3.5 GHz, 26.5 GHz and 50 GHz. Measurements include output level accuracy, carrier frequency accuracy, setting accuracy of modulation depth and deviation, weighted and unweighted spurious modulation, and modulation frequency response, distortion, and frequency. Resolution filters range from 10 Hz to 50 MHz, with FFT filters from 1 Hz to 30 kHz. Standard EMI filters are 200 Hz, 9 kHz and 120 kHz. Analysis functions include time-domain power, CCDF, noise/phase noise marker, standards-based channel and adjacent-channel power, and peak list marker for fast searches of all peaks within a given frequency range. The instrument's linearity is ±0.015 dB, and it has a broad level measurement range from –130 dBm to +30 dBm. Measurement bandwidth can be set between 100 Hz and 10 MHz. The power meter integrated into the FSMR is compatible with the Rohde & Schwarz NRP family of power sensors and can control power meters from other manufacturers as well. Other features include an RF frequency counter with 0.01 Hz resolution, and an audio input for calibration of modulation generators. The receiver is priced from $65,900.

Rohde & Schwarz
www.rsa.rohde-schwarz.com
HFeLink 226

faces. The electrical interface is fully compliant with telecom ITU-T G.703 (ES1) recommendations and can be connected using standard DIN 1.0/2.3 75 ohm cable connectors.

ITT Industries, Cannon
www.ittcannon.com
HFeLink 227

3 dB Hybrid Couplers

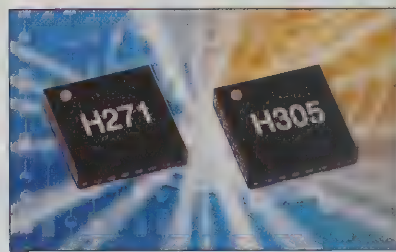
Anaren, Inc. has announced the availability of seven new Xinger-II® brand 3 dB couplers for use in wireless applications. The new family of hybrids covers 410-2799 MHz, including models optimized for CDMA2000, ISM, GSM, DCS, PCS, AMPS, 3G, UMTS, WiMAX and wireless LAN applications. The new Xinger-II 3 dB couplers are backed by the Anaren 100% On-Spec™ guarantee and B-There™ service commitment. Samples are available within 24 hours for qualified prototypes.

Anaren, Inc.
Tel: 800-411-6596
www.anaren.com
HFeLink 228

Oven Controlled Crystal Oscillators

Fox Electronics has introduced a new line of oven controlled crystal oscillators (OCXOs). Offered in frequencies from 5.000 to 50.000 MHz, these OCXOs are ideal for such applications as wireless products, RF broadcast, frequency references and test equipment. This new FPC5 Series of oscillators features stability from ±2 to 10 ppb, depending on temperature range, and 50–57% greater stability than previous versions. The parts are available in temperature ranges of 0°C to +50°C, –20°C to +70°C and –40°C to +75°C with stability, range dependent. The low profile OCXOs measure 2.0" W × 2.0" L × 0.79" H and feature 5.0 V operation and choice of HCMOS or sine versions. All oscillator models feature cold-welded SC-cut resonators. Pricing for a 10 MHz FPC5 Series OCXO is $147.50 in quantities of 100 units. Delivery is currently 10–12 weeks ARO.

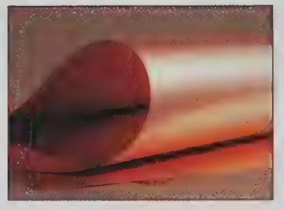
Fox Electronics
Tel: 888-GET-2-FOX
www.foxonline.com
HFeLink 229



Serially Controlled Digital Attenuators

Hittite Microwave Corporation announces the release of two new GaAs MMIC Digital Attenuators which are ideal for wireless infrastructure, test equipment, microwave radio and military applications from 0.7 to 3.8 GHz. The HMC271LP4 is a 5-bit Digital Attenuator with a 1 dB LSB and operates from 0.7 to 3.8 GHz with a typical insertion loss of 2.1 dB. It can be programmed to provide any attenuation state from 1 to 31 dB, in 1 dB steps with a ±0.5 dB accuracy. The HMC305LP4 is a 5-bit Digital Attenuator with a 0.5 dB LSB and covers 0.7 to 3.8 GHz with a typical insertion loss of 1.5 dB. It can be programmed to provide any attenuation state from 0.5 dB to 15.5 dB, in 0.5 dB steps with a ±0.3 dB accuracy. These new digital attenuators offer input IP3 of up to +52 dBm without the need for an internally generated or externally supplied negative voltage. Each attenuator is matched to 50 ohms at all attenuation levels, requires a single positive voltage supply (V_{dd})

Adhesiveless, All-Polyimide Flexible Circuit Materials

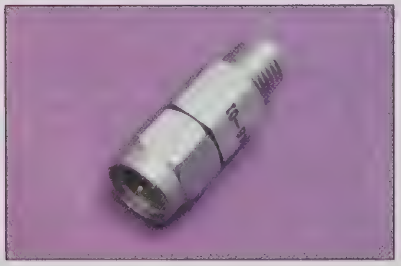


Rogers introduces its 2L-FCCL Adhesiveless, All-polyimide (API) Flexible Circuit Materials for use in cell phone hinge flex, LCD interconnection and other flexible interconnection applications. The materials offered include a single-clad, cast-on type product and a double-clad, laminated-type product. Both are available in rolls 250 mm and 500 mm (9.84 in. and 19.68 in.) wide. The new adhesiveless products are polyimide-based. They are well-suited for the manufacturing of circuits intended for use in high-density designs, harsh working environments, dynamic flexing applications as well as thin multilayer and rigid-flex circuits.

Rogers Corporation
www.rogerscorporation.com
HFeLink 230

of +5 VDC and accepts a three wire serial input. These digital attenuators are housed in 4 × 4 mm QFN leadless surface mount packages and offer identical PCB footprints and pin assignments.

Hittite Microwave Corporation
Tel: 978-250-3343
www.hittite.com
HFeLink 231



SMA Attenuator

XMA Corporation introduces the 2082-6346-XX stainless steel, SMA Attenuator, DC-6 GHz. This product offers the durability of a stainless steel body and coupling nut and solid electrical performance. Prices start at $11.99 for quantities of 1–99.

XMA Corporation
Tel: 603-222-2256
www.xmacorp.com
HFeLink 232

HMIC High-Barrier Mixers

M/A-COM has broadened its portfolio of surface mount, high-IP3, high-isolation HMIC high-barrier mixers. The MA4EXP400H-1277T is for use in base station and infrastructure equipment. Manufactured in a standard 3 mm square FQFP-N, 16-lead (MLP) package, the MA4EXP400H-1277T covers the frequency band of 3500–4500 MHz. These 50 ohm monolithic mixers require no additional components for circuit tuning. The mixer design produces an input IP3 in excess of +24 dBm for exceptional system linearity across the frequency band at LO drive levels of +17 dBm. The mixers also deliver exceptional LO-RF isolation, averaging better than 43 dB with conversion loss values less than 8.0 dB. The new MA4EXP family of mixers is available in high-volume production quantities through M/A-COM's direct sales channels and distribution channels worldwide. The MA4EXP400H-1277T is available at $1.95 each in acquisition pricing for 100,000 piece quantities.

M/A-COM, Inc.
Tel: 800-366-2266
www.macom.com
HFeLink 233

7-dBi WLAN Antenna

Nearson introduces the 7-dBi high gain rubber duck antenna. The antenna attaches directly to standard connectors found on industrial radios or 802.11b,g Access Points. Range of reception in many environments can be effectively tripled, reducing the need for extra Access Points, amplifiers or repeaters. Nearson's 7-dBi antennas are 11 inches tall, thin, flexible

and articulating. They come with industry standard SMA and TNC connectors as well as reverse polarity versions for FCC Part 15 compliance. There are models available with flying leads for OEM adoption with U.FL compatible and MMCX connectors. The 7-dBi antennas are available immediately for volume production.

Nearson
www.nearson.com
HFeLink 234

Lightning Protectors

The recently introduced GX series from PolyPhaser provides multistrike lightning protection for sensitive tower mounted amplifiers (TMA), tower top amplifiers (TTA) and active antenna systems, where DC voltage is required. With a fully weatherized housing and low throughput energy, GX series lightning protectors are available as DC pass or bias Tee versions and with N or 7/16 standard connectors. GX series protectors provide a return loss of over 20 dB and cover a frequency range from 400 up to 2500 MHz. Insertion loss is 0.1 dB maximum. DC pass models feature a RF power of 50 W and bias tee models deliver 300 W. Surge capabilities are in accordance with IEC 1000-4-5, 8/20 µs at 20 kA and IEC 1000-4-5, 10/35 µs at 5 kA. Surge throughput energy is up to or equal to 175 µJ maximum at 6 VDC to 2500 µJ at 60 VDC for the DC Pass version (6 kV/3 kA 8/20 µs) and 25 µJ maximum for the bias tee version. Insertion loss for

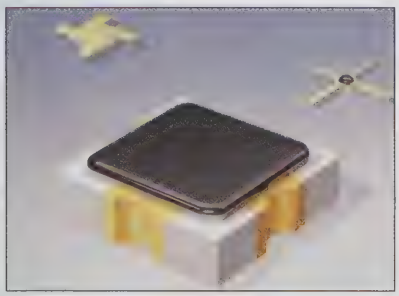
telemetry applications is 2.5/6.0 dB at 150/300 kHz. GX series lightning protectors have been designed for an operating temperature range from –50°C up to +85°C and a user voltage between 6 and 60 VDC. The generic lead time for GX series lightning protectors is three weeks and prices start from $107.

PolyPhaser
Tel: 800-325-7170
www.polyphaser.com
HFeLink 235

SMA Fixed Attenuator

JFW Industries announces a new DC-6 GHz low cost SMA fixed attenuator. This miniature HEX body device offers excellent VSWR, good attenuation accuracy and a wide operating temperature range of –65°C to +125°C. Capable of handling 2 W average power, this unit is ideal for multiple applications ranging from wireless installations through to laboratory test requirements.

JFW Industries, Inc.
Tel: 877-887-4539
www.jfwindustries.com
HFeLink 236



New Ring Quad Packaging

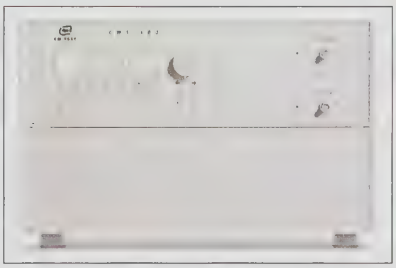
MicroMetrics low, medium and high barrier Schottky ring quads are now available in a new package. CS-17 is a square ceramic surface mount package with an epoxy top. It measures 0.060 inches square by 0.025 inches tall, with four bonding pads on the bottom. MicroMetrics Schottky ring quads are also available in a variety of other ring quad packages including: CS-12-4—a unique ceramic chip option, and CS-26R—a standard 4 lead ceramic surface mount option. They are also available in wafer and die form. Price and delivery is model specific.

Micrometrics, Inc.
Tel: 603-641-3800
www.micrometrics.com
HFeLink 237

New Design Kit

MagnaChip Semiconductor has announced a new Process Design Kit (PDK) supporting Agilent's RF Design Environment (RFDE) electronic design automation (EDA) software. MagnaChip's new PDK contains the full frequency range for its 0.18-micron mixed-signal/RF CMOS processes. All of MagnaChip's elements available for RF designers are modeled, including varactors, high-Q inductors integrated with Al and Cu, precision resistors, and high-density capacitors. RFDE-compatible models for MagnaChip's 0.18-micron mixed-signal processes are available from MagnaChip today.

MagnaChip Semiconductor
www.magnachip.com
Agilent Technologies, Inc.
www.agilent.com
HFeLink 238



New Version of Compact Simulator

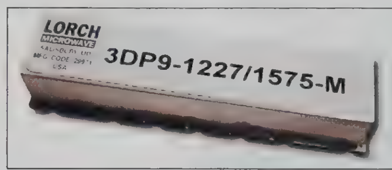
AR Worldwide has introduced a new version of its CWS500D compact simulator manufactured by EM Test for the AR Worldwide RF/Microwave Instrumentation division. The new addition is the Avionics Specification DO-160 Conducted Susceptibility Test. The

unit will be capable of testing to the highest levels of the DO-160 spec, which are Categories R, S, T, W and Y. The CWS500D simulator includes the signal generator, bi-directional coupler, power amplifier, 3-channel power meter, controller and Windows®-based operating software.

AR Worldwide
Tel: 215-723-8181
www.ar-worldwide.com
HFeLink 239

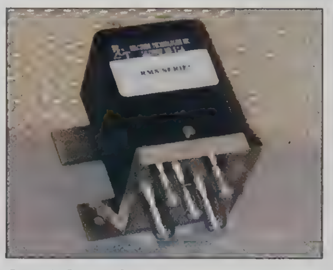
GPS Dual Band Diplexer

The 3DP9-1227/1575-M is a GPS dual band diplexer. The filter provides a 0.5 dB relative bandwidth over the center 30 MHz, with 1.5:1 VSWR over the pass band. The 3 dB bandwidths are 100 MHz typical. The insertion loss at center frequency is 1.2 dB (low band), and 1.65 dB (high band) max. The physical size is 1.25 × 0.50 × 0.38.



Lorch Microwave
Tel: 800-780-2169
www.lorch.com
HFeLink 240

1P4T Coaxial Relay



RelComm Technologies, Inc. has introduced a new 1P4T coaxial relay. This RMS Series boasts performance to 18 GHz–VSWR 1.50:1 maximum, Insertion Loss 0.50 dB maximum and Isolation better than –60 dB. This device exhibits a short electrical length and compact mechanical package measuring 1.30 inches square by 2.00 inches. Available in failsafe and latching configurations.

RelComm Technologies, Inc.
Tel: 410-749-4488
www.relcommtech.com
HFeLink 241

Precision Variable Power Divider

Microtech, Inc. designed and built a new precision variable power divider that operates from 34 to 36 GHz in the Ka (WR-28) Band. The device has a maximum VSWR of 1.25 with a minimum isolation of 30 dB and is capable of a phase shift of 360°. Power rating is 18 kW Peak and 500 watts average. The precision dial is capable of repeated resolution of less than 0.1 dB. This device is also available in other waveguide sizes.

Microtech, Inc.
Tel: 203-272-3234
www.microtech-inc.com
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What Conferences Should I Attend?

Editor,

My boss has just approved my travel and registration for at least one engineering conference this year. can you recommend which one I should go to? At least, can you give me several to choose from?

Thanks,

J. P.
Hartford, CT

Major High Frequency Events

OK, J.P. Here's a few suggestions:

In the RF/microwave industry, the single biggest event is the IEEE Microwave Theory and Techniques Society's International Microwave Symposium (IMS). This year, the IMS is held in Long Beach, Calif., June 11-17. IMS has an extensive technical papers program and a large exhibit hall featuring components, instruments and EDA tools. Check the web site for more information: www.ims2005.org.

This is not the only event that may be of interest. If you are interested in "marketplace research" to see what your colleagues and competitors are doing, then an industry-specific conference and trade show may be appropriate.

In the wireless communications business, the CTIA show (New Orleans, March 14-16—www.ctia.org) is the biggest event in the "cell phone" industry. Among the CTIA's current emphasis areas are 3G services and mobile Internet access.

The Wireless Communications Association (web site: www.wcai.com) has this year's main conference and trade show in Washington, DC, June 28-July 1. WCA emphasizes WLAN, point-to-multipoint and rural broadband access technologies.

Broadcast technology is featured at the huge NAB show, held each year in Las Vegas (April 16-21 this year—see www.nab.org). Technical papers are not academic level, but are useful, and the exhibition will have everything imaginable for audio and video production and transmission.

Technical Conferences

The MTT IMS venue also includes the RFIC Symposium (formerly the GaAs IC Symposium) and the Automatic RF Techniques Group (ARFTG). The RFIC symposium focus is what its name suggests: integrated circuits for RF and microwave. ARFTG focuses on high-performance measurement technologies for microwave applications. Visit www.rfic2005.org and www.arftg.org for more information.

If you are an antenna and propagation specialist, the main event is the IEEE AP-S International Symposium and USNC/URSI Meeting. This is a conference with strong international participation and an extensive technical program. This year's conference is July 3-8 in Washington, DC. See http://apursi2005.org for more information.

Smaller Conferences

There are many well-focused conferences that draw attendees in the low hundreds rather than the thousands. In our experience, these can be every bit as valuable as the big conferences. There are more chances for in-depth discussion with the paper authors, plus a very congenial atmosphere that can only be found at a small event. We highly recommend that you attend any of these that are nearby and, therefore, much less expensive to attend.

Two conferences of note are the IEEE Wireless and Microwave Technology Conference (WAMICON—www.wamicon.org), held April 7-8 in Clearwater, Fla. This conference has evolved from an internal conference of corporate supporters, faculty and students at the University of South Florida (USF). The conference covers a wide range of topics of interest to RF and microwave engineers.

Another conference that is growing is the IEEE Radio and Wireless Symposium (formerly the Radio and Wireless Conference—RAWCON). The next conference is actually next year, January 17-19, 2006 in San Diego, and it will be a much larger event than previous RAWCON conferences. See www.mttwireless.org for more information.

Present a Paper!

One of the best ways to participate in a conference is as a presenter. The "academic" level varies considerably among the various conferences, with some geared to practical techniques and product development case histories. It is not possible to list all the potential places to consider, but review our "Meetings and Events" column on page 8, and check out the conference listings at www.ieee.org.

IEEE or other engineering society journals and newsletters usually include listings of conferences. Of course, Internet search engines will turn up some prospective events, too.


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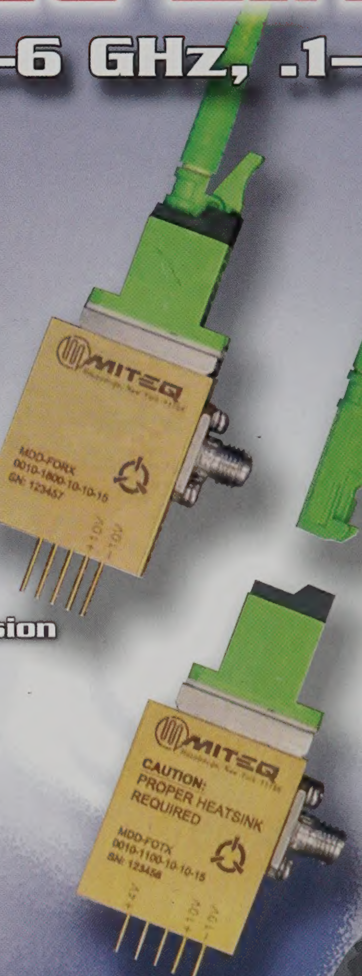
FIBER OPTIC LINKS
.01–3 GHz, .1–6 GHz, .1–11 GHz



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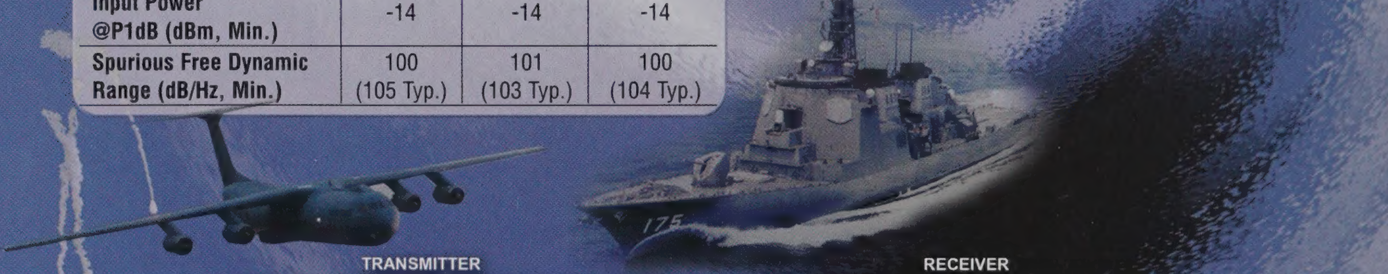
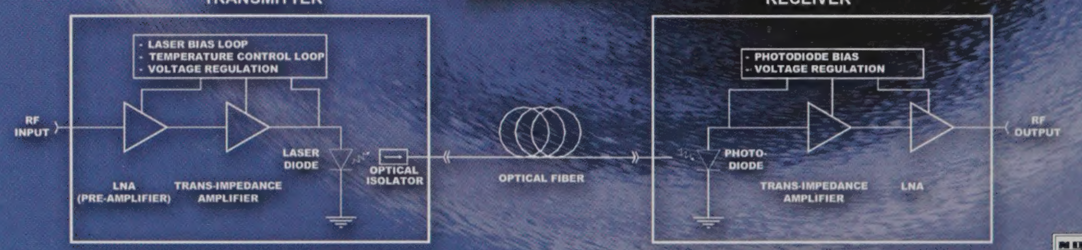
Frequency (GHz)	.01–3	0.1–6	0.1–11
Gain (dB)	10-20 (17 Typ.)	10-20 (18 Typ.)	10-20 (18 Typ.)
Noise Figure (dB, Max.)	15 (10 Typ.)	20 (14 Typ.)	20 (18 Typ.)
Group Delay (ns ptp, Typ.)	0.1	0.1	0.1
VSWR (In/Out)	2:1	2:1	2:1
Phase Noise (dBc, Typ.)	>100	>100	>100
Input Power @P1dB (dBm, Min.)	-14	-14	-14
Spurious Free Dynamic Range (dB/Hz, Min.)	100 (105 Typ.)	101 (103 Typ.)	100 (104 Typ.)





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